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OLD WEST REGIONAL COMMISSION
QUARTERLY REPORT

January [illegible], 1976 to March 31, 1976
Project Number 10470022

A Study to Evaluate Potential Physical, Biological, and Water Use Impacts of Water Withdrawals and Water Development on the Middle and Lower Portions of the Yellowstone River Drainage in Montana.

PLEASE RETURN

Submitted by

Gary J. Wicks, Director
Montana Department of Natural Resources
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Helena, Montana 59601

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To

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Project Coordinator
Old West Regional Commission
Room 306A Fratt Building
Billings, Montana 59102

June 15, 1976

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INTRODUCTION

The primary purpose of previous quarterly reports was to demonstrate progress on the project. In addition, however, each has presented, to some extent, elements of a final report--data, data analysis, literature review, and methodology descriptions.

This report goes a step further. Here, an attempt is made to present, on a preliminary basis, predictions of the potential impacts of water development on the middle and lower Yellowstone River Basin. The word "preliminary" must be emphasized. Predicitions presented here will change substantially through the acquisition of data during the second full field season, the continuing evolution of analytical methodologies, and more intimate exchanges of information among tasks. Therefore, these predictions must not be used or cited without the permission of the Montana Department of Natural Resources and Conservation.

As before, this report is organized according to tasks specified in the project contract. Such organization does not elucidate the overall strategy of the study. Figure 1 (adapted from Anderson 1975) demonstrates this strategy and references the tasks described in this report.

There are no discrepancies between the terms of the contract and the work performed.

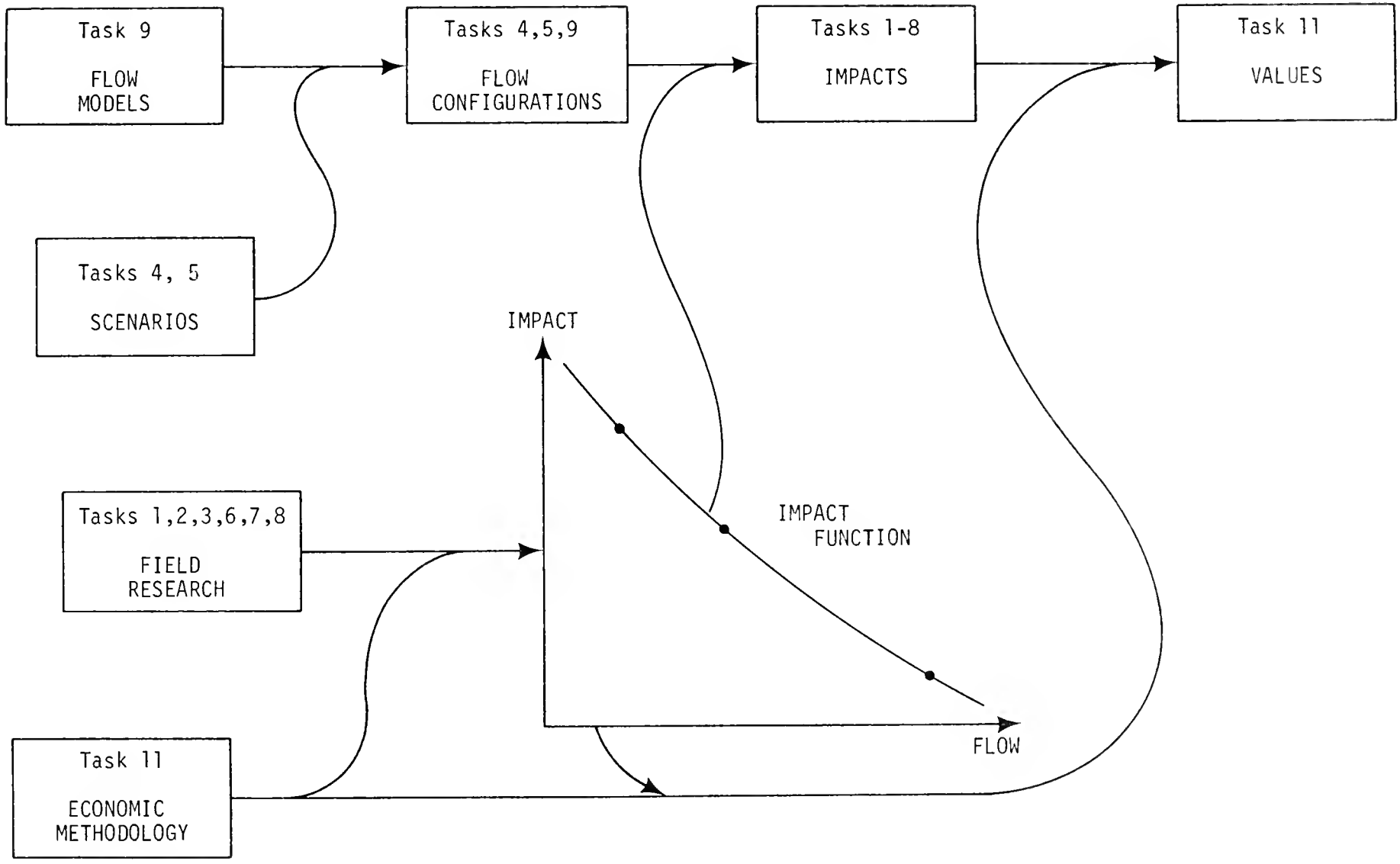


Figure 1. Information flow and plan of study.

TASK 1. INVESTIGATION OF AQUATIC COMMUNITIES . This task entails particular attention to the habitats of the Tongue River Basin. The Grantee shall inventory and investigate the life history of aquatic invertebrates and forage fish which support major fish populations in the lower and middle Yellowstone.

AQUATIC INVERTEBRATE STUDIES

INTRODUCTION

An objective of this task is to gain insights into the environmental requirements of the dominant macroinvertebrate genera and species of the Yellowstone River. Current velocity and water depth were chosen as the two independent variables that would be examined. Since current affects invertebrate distribution in several ways, eg. distribution of food, size of substratum, and current force, and because current and discharge are closely interrelated, studies of the effects of current on invertebrate distribution would be meaningful and would permit predictions about changes in invertebrate communities caused by altered flows. Because of the gently sloping gradient of the river channel, it was believed depth might be a valuable parameter as well; both current and depth are functions of discharge. When environmental requirements are established, one may predict how the population could change as the flow environment changes.

MACROINVERTEBRATE HABITAT REQUIREMENTS

Many factors regulate the distribution and abundance of stream-dwelling invertebrates; some of these are current speed, temperature, the substratum, vegetation, and dissolved substances (Hynes 1970). Other factors include competition, zoogeographical limitations and food availability.

Temperature and water chemistry exert the greatest influence on the composition of living communities considered over large areas, but, because of feeding and respiratory requirements, it is largely current that determines how communities actually are composed (Jaag and Ambuhl 1964, Chutter 1969). The ecological niche of many macroinvertebrates which inhabit flowing water is partially determined by current. In fact, some species are confined to narrow ranges of current speed. In the case of particular organisms, namely the net-building caddisflies (e.g. Hydropsyche, Cheumatopsyche, Parapsyche), it has been established that the nets require a definite current in order for them to function properly (Philipson 1954).

Many organisms need a current nearby but cannot tolerate being actually in it. There is often a tremendous difference in current velocity for an insect living on the top of a rock to that for one living under that rock, yet both may have current requirements. Because of the impossibility of taking measure-

ments at most points where macroinvertebrates exist, current velocity is usually measured at some reproducible depth, e.g. mid-depth, 0.6 times the depth from the bottom, or near the bottom (Hynes 1970).

There are unmistakable fast-current specialists (e.g. Baetis, Simulium, and Hydropsyche), while some other organisms find their optimum at low velocities (e.g. Gammarus, Hyalella, and Tricorythodes). It seems that each species prefers a certain range of current velocity.

In every turbulent flowing system, marginal effects develop in what are called boundary layers. Close to the substratum, movement of the water gradually slows owing to friction, and a boundary layer is formed in which the flow is strongly retarded, until, close to the substratum, it is stagnant (Jaag and Ambuhl 1964). The thickness of this boundary layer depends, among other things, on the velocity of the current above and the shape and roughness of the substratum. Extremely flattened organisms (e.g. Epeorus and Rhithrogena) make use of the boundary layer to avoid the current.

Many animals that live in flowing water can be maintained only in such water. These species either possess no ventilating organs or have changed or lost the function of those organs in the course of their evolutionary development. They are extremely sensitive to still water and quickly die in it (e.g. most Plecoptera).

Macrodistribution of aquatic invertebrates can be explained with difficulty as habitat gradually changes moving downstream. Cummins (1975) described food as the ultimate determinant of macroinvertebrate distribution and abundance in nondisturbed running waters. The current regime, velocity, and turbulence set the limits on the range of sediment particle sizes present as well as controlling such features as the growth of periphyton, macrophytes, and accumulation of particulate detritus. The size of particles present decreases in a downstream direction (Macan 1974, Hynes 1970); this results in community variation in primary producers, macroinvertebrates, and fish. These community changes may be generally placed into three categories or habitat subsystems: 1) erosional zone; 2) intermediate zone; and 3) depositional zone. Each zone has a characteristic physical-chemical makeup and a characteristic fauna. These three subhabitats appear to correspond to fish distribution in the Yellowstone River as follows: erosional zone--salmonid fishes; intermediate zone--transition from salmonid to nonsalmonid fishes; depositional zone--warm-water, nonsalmonid fishes. (The intermediate (transition) zone is illustrated by shading in figure 2 and tables 4-7.)

ACCOMPLISHMENTS DURING THE QUARTER

All benthic samples taken, along with current and depth measurements, were analyzed. Several samples taken in the Livingston area were also processed.

The graduate student working on the middle Yellowstone River was helped with sampling and identification difficulties.

Several collecting trips were made in an attempt to collect adult insects.

METHODS

Many sampling methods were used to collect data on invertebrate distribution along the Tongue and Yellowstone rivers. Published data were also examined for species distribution. Twenty sampling stations were established on the Yellowstone (table 1, figure 2) and eight on the Tongue (figure 3), beginning in August 1974. In some cases, identification of nymphs and larvae was made to species, but, for many species, adults were used to verify species identifications.

All samples gathered for the habitat needs phase of the research were collected from two stations, Glendive and Intake, monthly from August through November. A total of 24 samples were taken at each station each month. All samples were taken with a modified Turtox bottom net with dimensions of 18"x8" and 10" deep (46x20x25.4 cm). A 6' handle was used to hold the net perpendicular to the current. A wire frame 17"x16" (43.2cm x 40.6cm) was attached to the bottom lip of the net frame perpendicular to the net opening in such a way that the wire frame rested on the stream bottom. When the area within the frame was disturbed benthic organisms were carried into the number 20 mesh net. Net material was added to each side of the 17"x16" wire frame to minimize side wash-out of organisms. This technique can be used as long as the water is shallow enough to wade. The bottom outlined by the frame is merely stirred with the foot. Water depth and current speed at six tenths of the depth were determined in the center of each sample site.

MACROINVERTEBRATE DISTRIBUTION

Table 2 is a checklist of the macroinvertebrates found in the Tongue and Yellowstone rivers. This checklist is as complete as possible and utilizes all published sources available as well as the data gathered during this study. Distributional records were taken from Stadnyk (1971), Gaufin et al. (1972), and Thurston et al. (1975). Latest available taxonomic keys were utilized and, for the following groups, experts were consulted: Trichoptera (D. G. Denning, Moraga, CA); Plecoptera (R. Baumann, Brigham Young Univ., Provo, UT); Elmidae (H. P. Brown, Univ. of Oklahoma, Norman, OK); Chironomidae (L. Curry, Central Michiga State Univ., Mt. Pleasant, MI); Mollusca and Oligochaeta (D. Klemm, EPA, Cincinnati, OH); Odonata and Hemiptera (G. Roemhild, Montana State University, Bozeman, MT).

Where species identification was not possible the most likely species is listed in parentheses using most recent available distribution data. In table 2, under Order Diptera, several genera are listed for the family Chironomidae; this is the only place these genera will appear in this report because of uncertain identifications. This family is extremely difficult to identify and most available keys are regional and/or incomplete. It is also very difficult to have identifications confirmed. Currently this group is being examined by L. Curry of Central Michigan State University, Mount Pleasant, MI; hopefully his work will be completed in time to add the correct genera and species to this list before the final report.

TABLE 1. Yellowstone River sampling stations.

No.	Location	County	Elevation	River Mile *
1	Corwin Springs	Park	5110 ft.	549
2	Mallard Rest Access	"	4620	515
3	above Livingston	"	4490	501
4	above Shields River	"	4380	497
5	Grey Bear access	Sweetgrass	4100	468
6	below Greycliff	"	3880	444
7	Columbus	Stillwater	3566	411
8	Laurel	Yellowstone	3294	391
9	Duck Creek Bridge	"	3140	360
10	Huntley	"	3110	349
11	Custer	"	2720	300
12	Bighorn River	Treasure	2700	296
13	Myers	"	2640	279
14	Forsyth	Rosebud	2490	234
15	Miles City	Custer	2335	184
16	Terry	Prairie	2190	138
17	Glendive	Dawson	2045	93
18	Intake	"	1998	71
19	Sidney	Richland	1892	30
20	Cartwright,N.D.	McKenzie	1850	9

* Mouth of the Yellowstone River is river mile 0.0 .

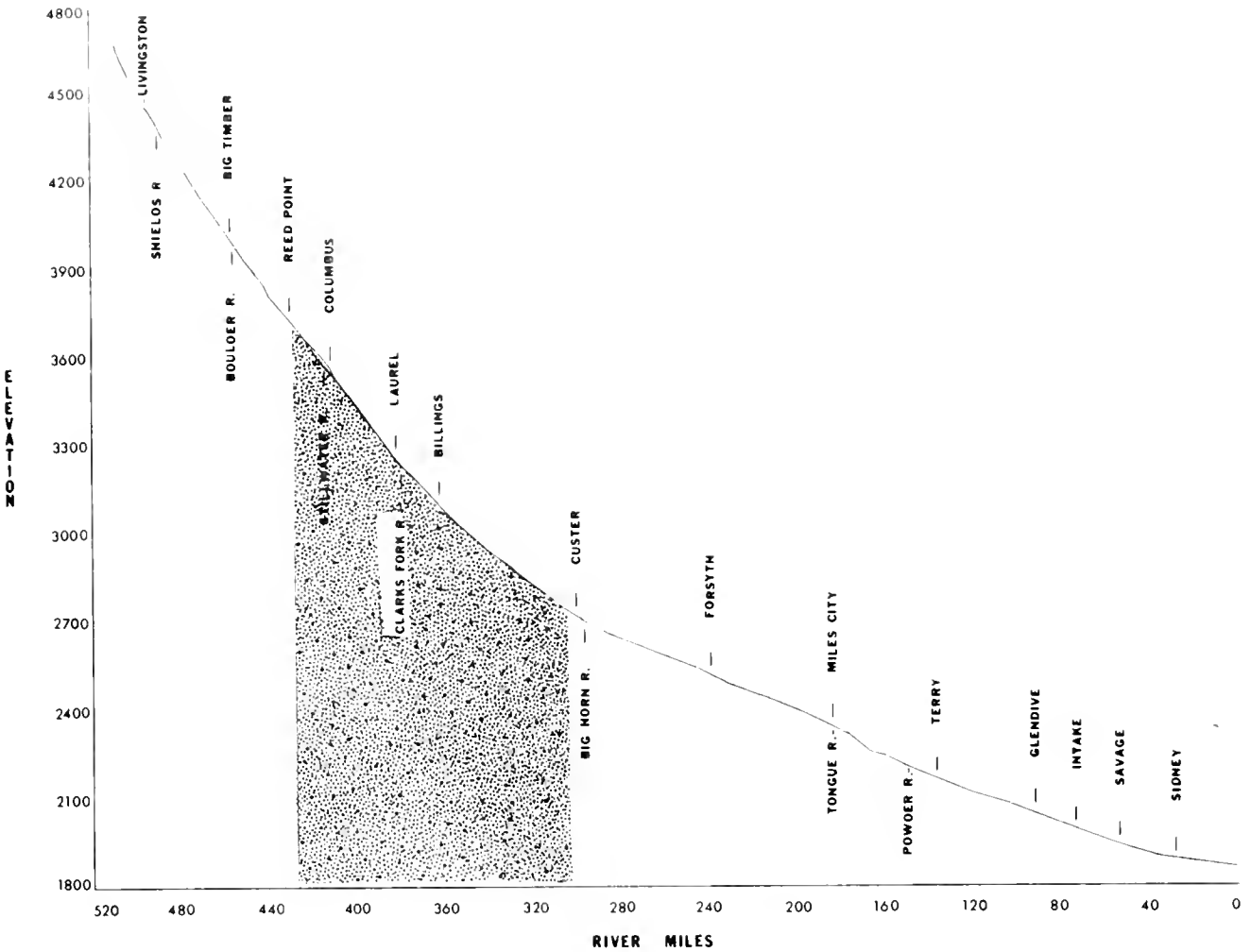


Figure 2. Invertebrate sampling stations established on the Yellowstone River and their relative position along a longitudinal and elevational gradient.

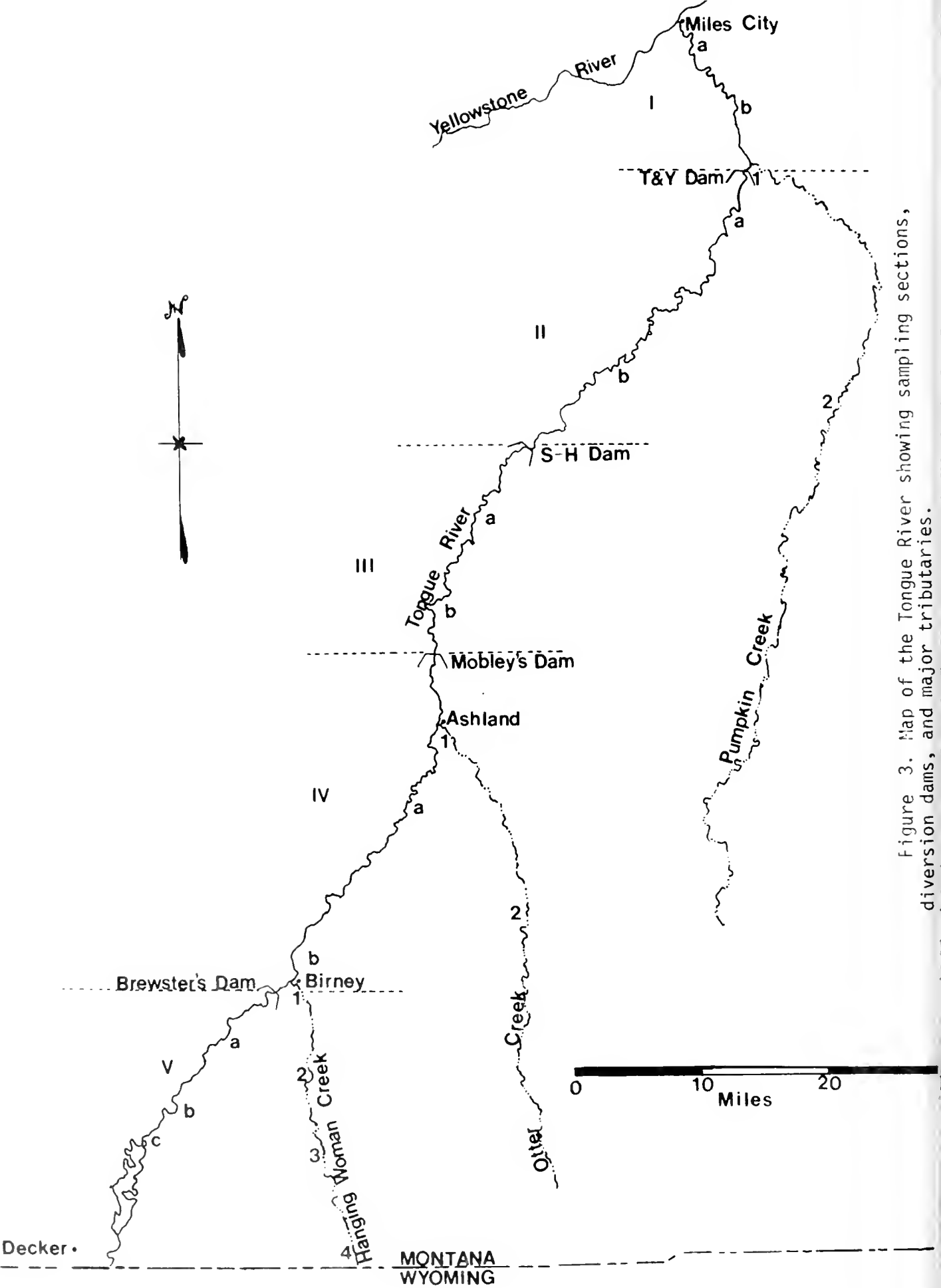


Figure 3. Map of the Tongue River showing sampling sections, diversion dams, and major tributaries.

Table 2. Checklist of the aquatic macroinvertebrates of the Tongue (t) and Yellowstone (y) rivers.

Phylum Arthropoda		
Order Ephemeroptera		
Family Siphlonuridae		
Ameletus (oregonensis McD.?)	y	
Isonychia (sicca campestris McD. ?)	y	
Family Baetidae		
Baetis (alexanderi M.S. Edmunds & Jensen)	y	t
Baetis parvus Dodds	y	t
Baetis (propinquus Walsh)	y	
Baetis tricaudatus Dodds	y	
Centroptilum sp. A	y	
Dactylobaetis cepheus Traver & Edmunds	y	t
Pseudocloeon sp. A	y	
Family Oligoneuriidae		
Lachlania powelli Edmunds	y	
Family Heptageniidae		
Epeorus (Iron) albertae (McD.)	y	
" (") longimanus (Eaton)	y	
Heptagenia elegantula (Eaton)	y	t
Rhithrogena undulata (Bks.)	y	t
Stenonema terminatum (Walsh)	y	t
Stenonema prob n. sp.	y	
Family Ametropodidae		
Ametropus (neavei McD.)?	y	
Family Leptophlebiidae		
Choroterpes albiannulata McD.	y	t
Leptophlebia gravastella Eaton	y	t
Paraleptophlebia bicornuta (McD.)	y	
" heteronea (McD.)	y	
Traverella albertana (McD.)	y	t
Family Ephemerellidae		
Ephemerella (Attenuatella) margarita N.	y	
" (Caudatella) h. heterocaudata McD.	y	
" (") hystrix Traver	y	
" (Drunella) doddsi Needham	y	
" (") g. grandis Eaton	y	
" (Ephemerella) inermis Eaton	y	t
" (Serratella) tibialis McD.	y	
" (Timpanoga) h. hecuba (Eaton)	y	
Family Tricorythidae		
Tricorythodes minutus Traver	y	t
" sp. A	y	
Family Ephemeridae		
Ephemera sp. A	y	

TABLE 2.(continued).

Family Polymitarcidae		
Ephoron album (Say)	y	
Family Caenidae		
Brachycercus (*prudens* McD.?)	y	t
Caenis latipennis Bks.	y	
Family Baetiscidae		
Baetisca sp.A	y	t
Order Trichoptera		
Family Rhyacophilidae		
Rhyacophila bifila Bks.	y	
Family Helicopsychidae		
Helicopsyche borealis (Hagen)	y	
Family Glossosomatidae		
Glossosoma sp. A	y	t
" *traviatum* Bks.	y	
" *velona* Ross	y	
Family Psychomyiidae		
Polycentropus cinereus Hagen	y	
Psychomyia flavida Hagen	y	
Family Hydropsychidae		
Arctopsyche grandis Bks.	y	
Cheumatopsyche sp. A	y	t
" *analis* (Bks.)	y	
" *campyla* Ross	y	
" *lasia* Ross	y	
" *enonis* Ross	y	
Hydropsyche sp. A	y	t
" near *alhedra* Ross		t
" *cockerelli* Bks.	y	
" *corbeti* Nimmo	y	
" *occidentalis* Bks.	y	
" *oslari* Bks.	y	
" *separata* Bks.	y	
Family Hydroptilidae		
Hydroptila sp. A	y	t
" *waubesiana* Betten	y	
Agraylea multipunctata Curtis	y	
Ochrotrichia potomas Denning	y	
Neotrichia sp. A	y	
Family Leptoceridae		
Athripsodes sp. A	y	
Leptocella sp. A	y	
Oecetis sp. A	y	t
" *avara* (Bks.)	y	
" *disjuncta* (Bks.)	y	
Triaenodes frontalis Bks.	y	

TABLE 2. (continued).

Family Lepidostomatidae			
Lepidostoma n. sp.		y	
"	pluvialis Milne	y	
"	veleda Denning	y	
Family Brachycentridae			
Amiocentrus aspilus (Ross)		y	
Brachycentrus sp. A		y	t
"	americanus (Bks.)	y	
"	occidentalis Bks.	y	
Family Limnephilidae			
Hesperophylax incisus Bks.		y	
Limnephilus taloga Ross		y	
Order Plecoptera			
Family Nemouridae			
Nemoura (Prostoia) besametsa Ricker		y	
"	(Zapada) cinctipes Bks.	y	
Paraleuctra sara Claassen		y	
Capnia (Capnia) confusa Claassen		y	
"	(") gracilaria "	y	
"	(") limata Frison	y	
"	(Utacapnia) distincta Frison	y	
"	(") poda Nebeker & Gaufin	y	
Eucapnopsis vedderensis Ricker		y	
Isocapnia missourii Ricker		y	
"	vedderensis (Ricker)	y	
Brachyptera (Taenionema) fosketti Ricker		y	t
"	(") nigripennis (Bks)	y	
"	(") pacifica (Bks)	y	
Family Pteronarcidae			
Pteronarcella badia (Hagen)		y	
Pteronarcys californica Newport		y	
Family Perlodidae			
Arcynopteryx (Skwala) parallela (Frison)		y	
Isogenus (Cultus) aestivalis (N & C)		y	
"	(") tostonus Ricker	y	
"	(Isogenoides) frontalis colubrinus Hagen	y	t
"	(") elongatus Hagen	y	
Isoperla fulva Claassen		y	
"	mormona Bks.	y	
"	longiseta Bks.	y	
"	patricia Frison	y	
Family Chloroperlidae			
Alloperla (Suwallia) pallidula (Bks)		y	
"	(Sweltsa) coloradensis (Bks)	y	
"	(Alloperla) severa Hagen	y	
"	(Triznaka) signata (Bks)	y	

TABLE 2.(continued).

Family Perlidae		
Acroneuria abnormis	y	t
" (*Hesperoperla*) *pacifica* Bks.	y	
Claassenia sabulosa (Bks)	y	
Order Isopoda		
Family Asellidae		
Asellus racovitzai racovitzai Williams	y	
Order Lepidoptera		
Family Pyralidae		
Cataclysta sp. A	y	t
Order Hemiptera		
Family Corixidae		
Callicorixa utahensis (Hung.)	y	
Cenocorixa audeni Hung.	y	
Sigara alternata Say	y	
Trichocorixa borealis Sailer	y	
Family Naucoridae		
Ambrysis mormon Mont.	y	
Family Veliidae		
Rhagovelia distincta Champion	y	t
Family Cerridae		
Gerris remigis Say	y	
Family Nepidae		
Ranatra fusca P.B.	y	
Order Odonata		
Family Gomphidae		
Gomphus sp. A	y	t
Ophiogomphus sp. A	y	t
Family Agrionidae		
Calopteryx sp. A		t
Family Coenagrionidae		
Argia sp. A		t
Amphiagrion sp. A	y	t
Enallagma sp. A	y	
" *ebrium* (Hagen)		t
Ischnura sp. A		t
Order Coleoptera		
Family Dytiscidae		
Oreodytes sp. A	y	

TABLE 2.(continued).

Family Dryopidae		
Helichus sp. A	y	
Family Elmidae		
Dubiraphia sp. A	y	t
Microcylloepus pusillus (LeConte)	y	t
Optioservus quadrimaculatus (Horn)	y	
Stenelmis sp. A	y	t
Zaitzevia parvula (Horn)	y	
Family Gyrinidae		
Gyrinus sp. A	y	
Order Diptera		
Family Blepharoceridae		
Agathon sp. A	y	
Family Ceratopogonidae	y	
Family Chironomidae		
Subfamily Tanypodinae		
Ablabesmyia sp. A	y	
Clinotanypus sp. A	y	
Cryptocladius sp. A	y	
Procladius sp. A	y	
Subfamily Chironominae		
Chironomus sp. A	y	
Cryptochironomus sp. A	y	
Microtendipes sp. A	y	
Paralauterborniella sp. A	y	
Rheotanytarsus sp. A	y	t
Stictochironomus sp. A	y	
Subfamily Diamesinae		
Diamesa sp. A	y	t
Pseudodiamesa sp. A	y	
Subfamily Orthocladiinae		
Brillia sp. A	y	
Cardiocladius sp. A	y	t
Cricotopus sp. A	y	
Eukiefferiella sp. A	y	t
Metriocnemus sp. A	y	
Orthocladius sp. A	y	t
Trichocladius sp. A	y	
Family Dolichopodidae	y	
Family Empididae		
Hemerodromia sp. A	y	
Family Muscidae		
Limnophora sp. A	y	

TABLE 2.(continued).

Family Rhagionidae		
Atherix variegata Walker	y	
Family Simuliidae		
Simulium vittatum Zett.	y	t
Family Tanyderidae		
Protoplasa fitchii O.S.	y	
Family Tipulidae		
Dicranota sp. A	y	
Hexatoma sp. A	y	t
Holorusia sp. A	y	
Tipula sp. A	y	
Order Acari		
Suborder Prostigmata (Hydracarina)	y	
Order Amphipoda		
Family Gammaridae		
Gammarus lacustris Sars	y	
Family Talitridae		
Hyalella azteca (Sau.)	y	
Phylum Platyhelminthes		
Class Turbellaria		
Family Planariidae		
Dugesia sp. A	y	t
Phagocata sp. A	y	
Phylum Annelida		
Subclass Oligochaeta	y	t
Family Naididae		
Dero digitata Muller		t
Nais variabilis Piguet	y	
Ophidonais serpentina Muller	y	
"Megadrille"		t
Phylum Mollusca		
Order Basommatophora		
Family Lymnaeidae		
Lymnaea sp. A	y	t
Family Physidae		
Physa sp. A	y	t
" *concolor* (Say)		t
Family Ancylidae		
Ferrissia sp. A	y	t
Order Eulamellibranchia		
Family Unionidae		
Lampsilis siliquoidea (Barnes)	y	t
Order Heterodonta		
Family Sphaeriidae		
Pisidium sp. A		t
Sphaerium simile (Say)		t

The distribution of all mayflies (Ephemeroptera) known to occur in the Yellowstone River, 37 species variously distributed, is presented in table 3. In this table, stations 7-12 are shaded and represent the probable location of the transition zone between cold (salmonid) and warm-water fish. It would also correspond to the intermediate zone between the erosional and depositional habitat subsystems outlined by Cummins (1975) for large river systems. Note that 4 species were collected throughout the study area and a fifth species (Ephemerella inermis) was missing only from the lowermost sampling stations. The number of mayfly species found at each station is shown in figure 4. Station 5 yielded the largest number of species (19) and stations 19 and 20 the fewest with 10 species. No patterns of mayfly distribution are apparent through the transition zone. Along the entire river the community exhibits a gradual shift from mountain fauna to prairie fauna, but the number of species is almost constant.

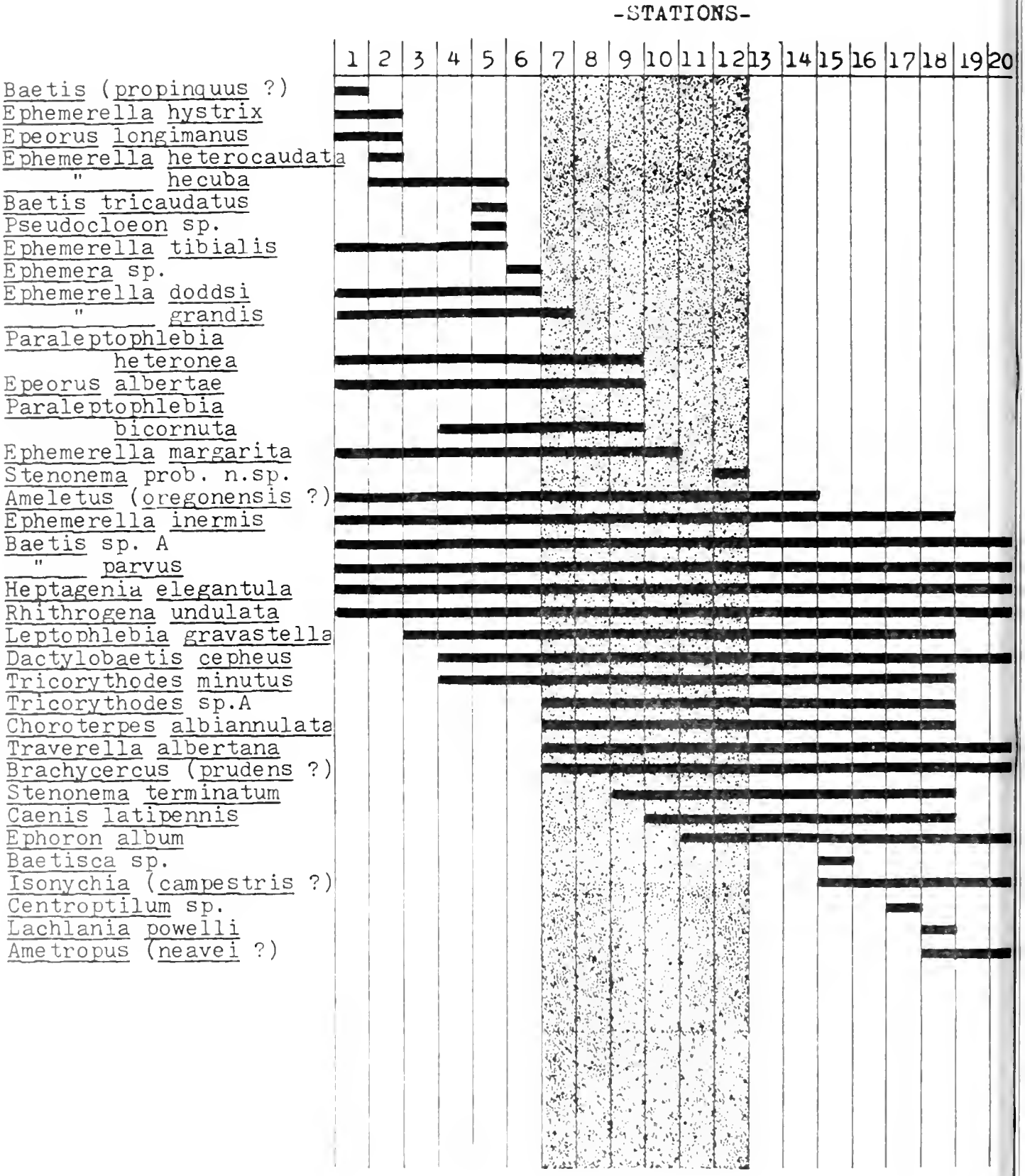
The longitudinal distribution of the stoneflies (Plecoptera) differs considerably from that of the Ephemeroptera (table 4). A total of 32 species of stoneflies was identified in the study area. No single species was collected at every station. Data available for this order are probably the most accurate because of the work of Stadnyk (1971) and Gaufin et al. (1972). Most of the fauna are probably adapted to the conditions found in the upper river. Twelve species drop out in the transition zone and five species could be classified as prairie stream forms. Acroneuria abnormis, probably washed out of the Tongue River where it is abundant, was collected only at Station 15. The number of Plecoptera species decreases steadily downstream (figure 4). Generally, the nonprairie stoneflies appear to have habitat requirements similar to those of the salmonid fishes.

Caddisfly (Trichoptera) distribution in the Yellowstone River is presented in table 5. The present species list contains 36 species and additional species will probably be collected. Distributional patterns are less distinct than with the Ephemeroptera and Plecoptera. In most cases caddisfly larvae cannot be identified to species; adult males are necessary. The present distribution is incomplete because all stations were not sampled for adults with equal frequency. For example, Station 9, which had the largest number of species, was sampled most intensively. Generally, caddisfly distribution is similar to that of the Plecoptera with a steady decline in the number of species in the downstream direction. The genera Hydropsyche and Cheumatopsyche are abundant throughout the river but dominate in the lower 10 stations.

The distribution of the remaining aquatic orders is given in table 6. The order Diptera is widely distributed throughout the river with the family Chironomidae being the most abundant. Protoplasa fitchii, an interesting species previously unreported from Montana, was captured at several stations. Representatives of the remaining orders did not illustrate any distributional trends and, with the exception of the Oligochaeta, were never abundant.

Distribution of macroinvertebrates in the Tongue River, shown in table 7, is complex and not easily explained. The fauna is similar to the Yellowstone fauna in many respects but there are several differences. The stonefly Acroneuria abnormis, the elmid beetle Stenelmis sp. and the mussell Lampsilis

TABLE 3. Ephemeroptera of the Yellowstone River.



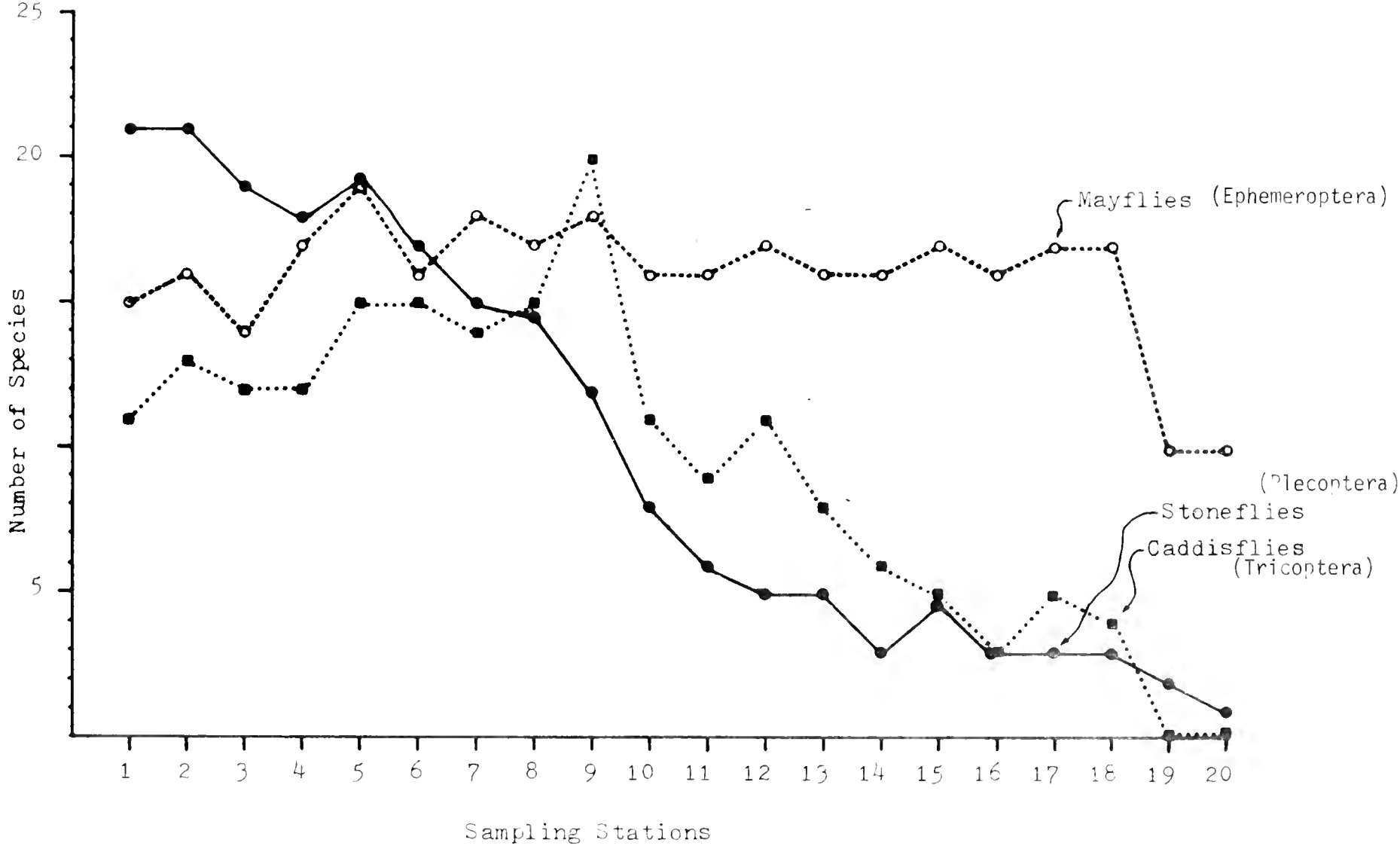


Figure 4. Number of species of the three major orders found at each sampling station in the Yellowstone River.

TABLE 4. Plecoptera of the Yellowstone River.

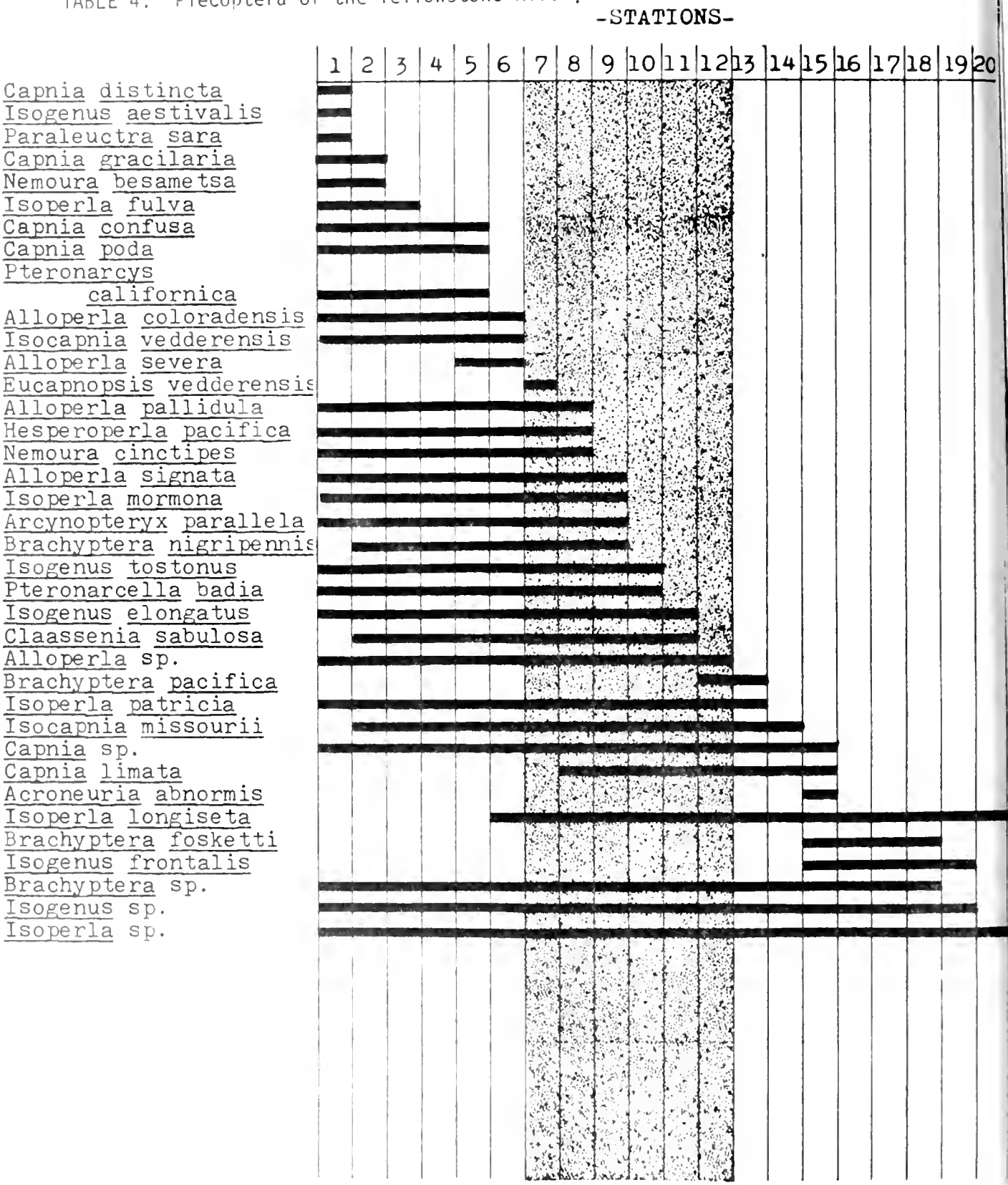


TABLE 5. Trichoptera of the Yellowstone River.

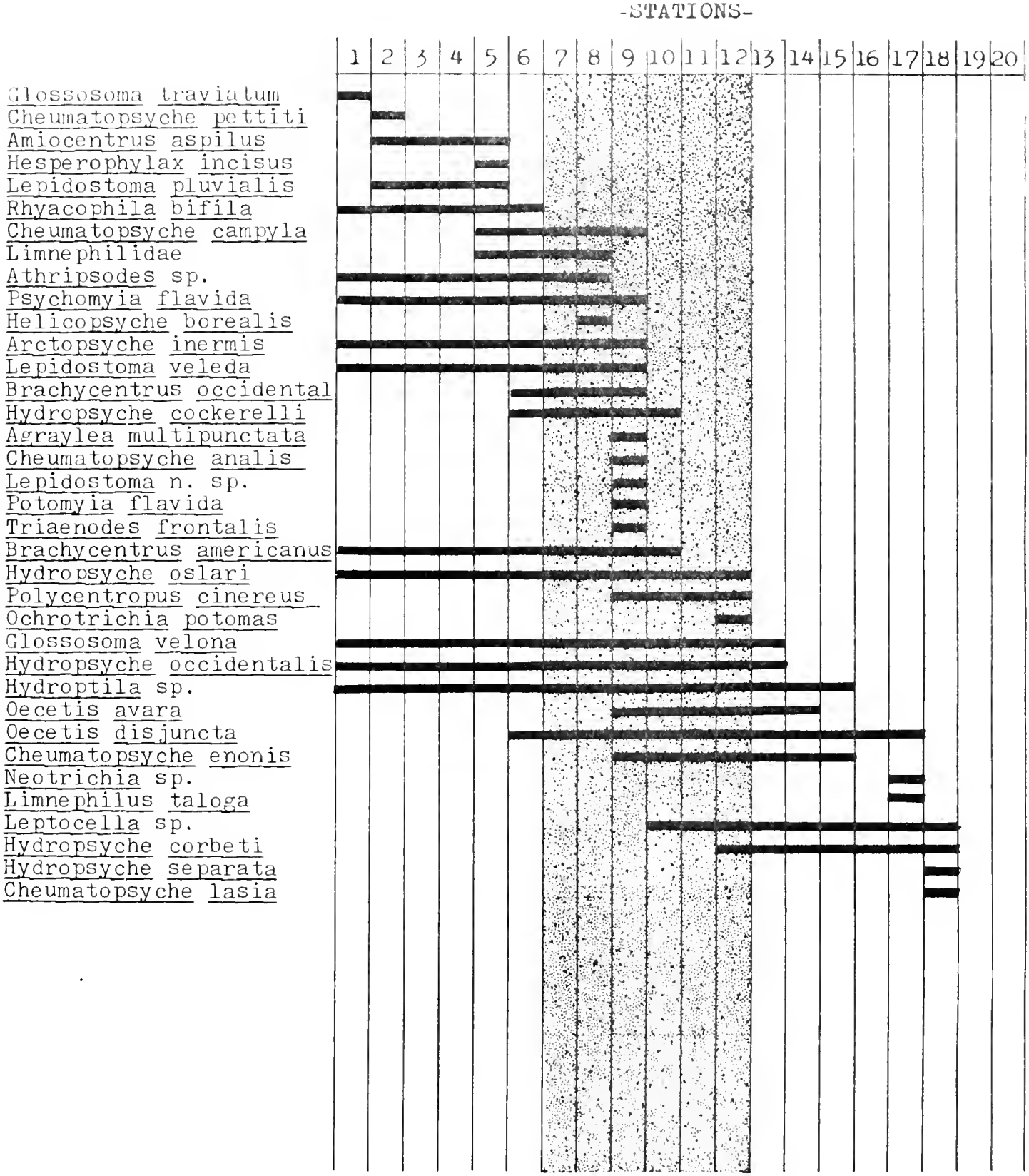


TABLE 6. Aquatic invertebrates of the Yellowstone River.

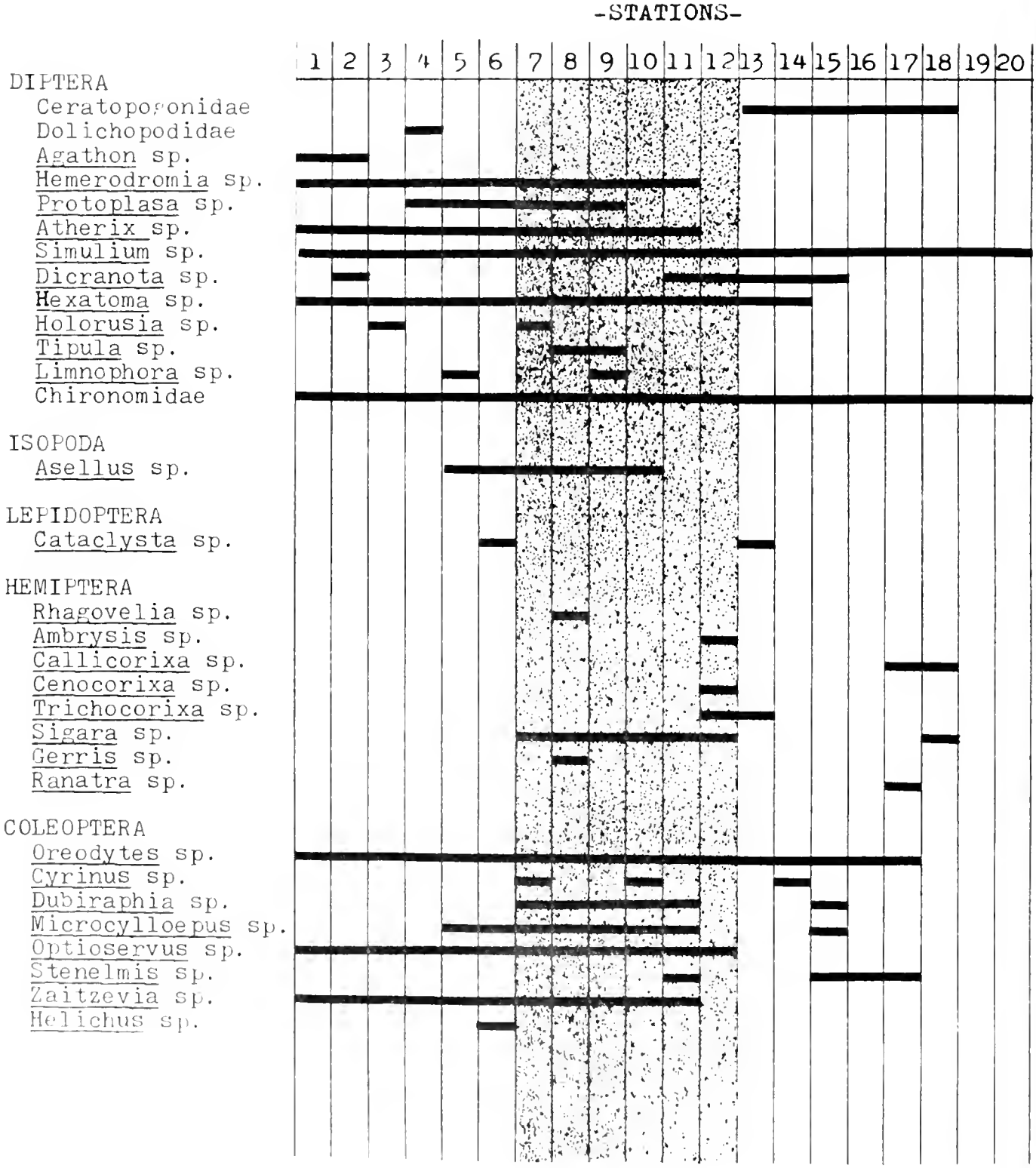


TABLE 6. (continued).

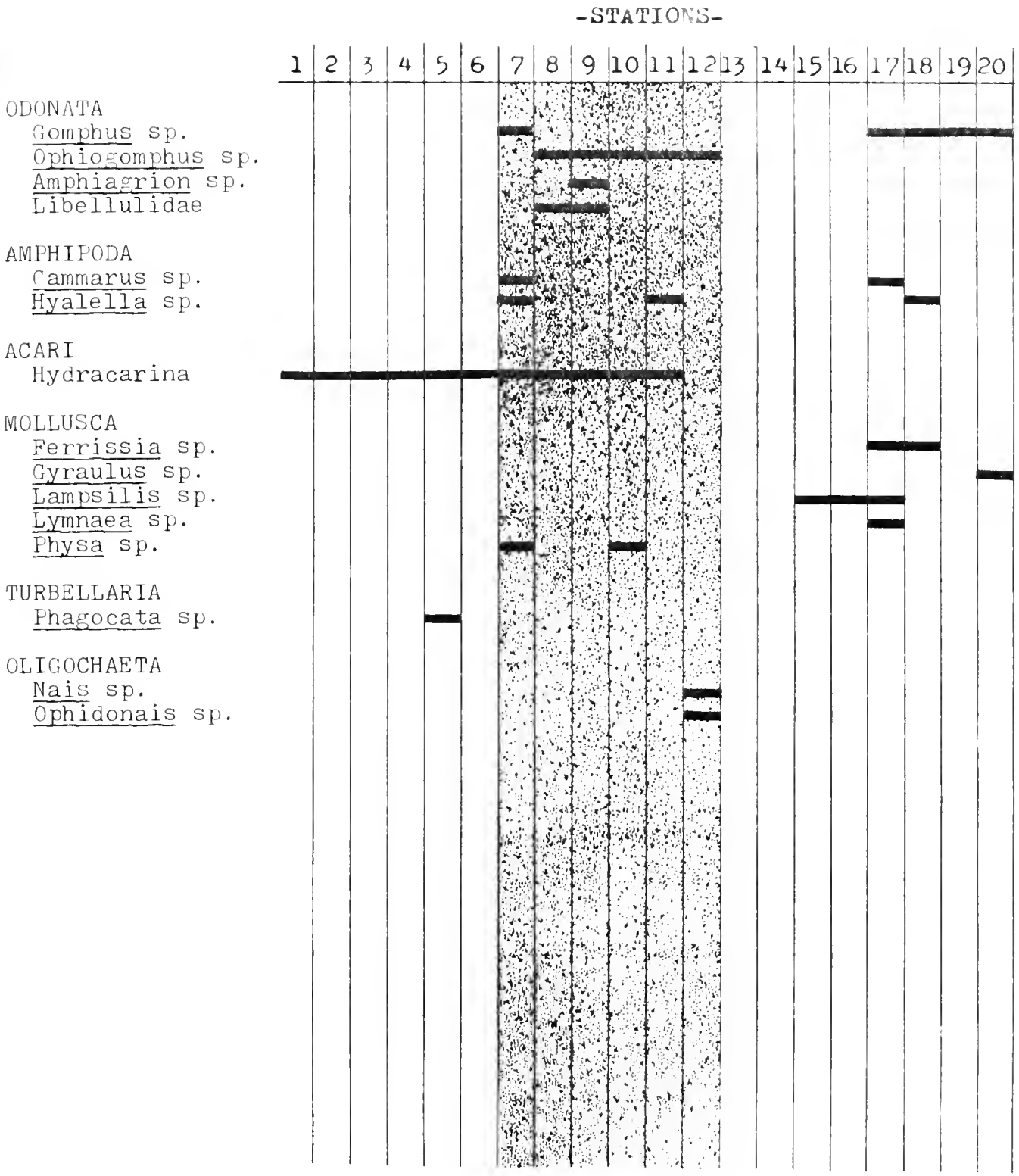


TABLE 7. Macroinvertebrate fauna of the Tongue River, Montana.

Taxa	Sta. no. 8 Dam Section	7 Hosford	6 Birney	5 Ashland	4 Viall	3 S - H	2 Orcutt	1 Keogh
Ephemeroptera								
Baetis spp.	X	X	X		X	X		
Baetisca sp.						X		
Brachycercus sp.					X			
Choroterpes sp.				X		X		
Dactylobaetis sp.						X		
Ephemerella sp.	X	X	X	X	X	X	X	
Heptagenia sp.			X	X	X	X	X	
Leptophlebia sp.			X	X			X	
Rhithrogena sp.			X	X	X	X	X	X
Stenonema sp.		X				X		
Traverella sp.			X	X	X	X	X	
Tricorythodes sp.	X	X	X	X	X	X	X	
Trichoptera								
Brachycentrus sp.	X		X	X	X	X	X	X
Cheumatopsyche sp.	X	X	X	X	X	X	X	X
Glossosoma sp.		X	X					
Hydropsyche sp.	X	X	X	X	X	X	X	X
Hydroptila sp.	X	X	X				X	X
Mystacides sp.			X	X			X	
Oecetis sp.			X	X		X	X	
Plecoptera								
Acroneuria sp.			X			X	X	X
Brachyptera sp.			X		X	X	X	X
Isogenus sp.			X	X	X	X	X	X
Coleoptera								
Dubiraphia sp.		X	X					
Microcylloepus sp.		X	X	X				
Stenelmis sp.		X	X	X	X	X	X	X

TABLE 7.(continued).

Taxa	Sta. no.	8 Dam Section	7 Hosford	6 Birney	5 Ashland	4 Viall	3 S - H	2 Orcutt	1 Keogh
Mollusca									
Ferrissia sp.		X	X	X					
Gyraulus sp.			X						
Lymnaea sp.		X	X						
Lampsilis sp.									X
Physa sp.		X	X	X					
Pisidium sp.			X				X		
Sphaerium sp.			X						
Odonata									
Argia sp.			X					X	
Calopteryx sp.			X			X	X		
Enallagma sp.									
Ischnura sp.			X						
Gomphus sp.				X					
Ophiogomphus sp.		X	X	X	X	X	X		
Lepidoptera									
Cytaclysta sp.		X	X				X	X	
Turbellaria									
Dugesia sp.		X	X	X	X		X	X	
Hemiptera									
Corixidae		X	X	X				X	X
Rhagovelia sp.					X				
Diptera									
Chironomidae		X	X	X	X	X	X	X	X
Cardiocladius sp.		X		X					
Diamesa sp.		X		X					
Eukiefferiella sp.				X					X
Orthocladius sp.		X					X		
Rheotanytarsus sp.				X					
Simuliidae									
Simulium sp.		X	X	X	X	X	X	X	
Tipulidae									
Hexatoma sp.				X	X		X	X	X
Oligochaeta			X	X					

are abundant in the Tongue but rare in the Yellowstone. Odonates are more abundant and diverse in the Tongue River.

CURRENT AND DEPTH REQUIREMENTS FOR INVERTEBRATES

Data from the current-depth studies at Glendive and Intake are summarized in table 8. In general, current and depth means are similar for both stations and all sampling times. Numbers of taxa and individuals varied greatly, however. At Glendive the mean number of taxa increased from 3.9 in August to 9.0 in November; a similar trend was evident in the Intake samples. The mean number of individuals per sample increased from 9.1 to 149 at Glendive and from 37.9 to 65.8 at Intake. More taxa and more individuals were captured in the October and November samples at both stations than during August and September. December samples would have been valuable but were unavailable because the lower river froze on November 30, 1975.

Population estimates from 24 samples at each station expressed in numbers per m^2 are shown in tables 9-12. In August (table 9) the fauna was dominated by Traverella and Hydropsyche . There was a large difference in the total number of individuals collected at Glendive (1222) and Intake (5199).

In September (table 10) Hydropsyche again were abundant, as were Chronomidae. Totals were comparable for Glendive (2964) and Intake (3638).

Hydropsyche and Chironomidae again dominated in the October samples (table 11). Number of taxa and total number of individuals greatly increased at both stations.

November samples again found Hydropsyche and Chironomidae dominant (table 12). Totals were again high at Glendive (20,245) but were considerably reduced at Intake (8988).

All 48 samples taken each month were pooled to illustrate which orders dominate the fauna (table 13): Ephemeroptera and Trichoptera, with Diptera a close third. Ephemeroptera monthly percentages ranged from 11.7 to 73.6 percent, while Trichoptera totals varied from 21.1 to 56.3 percent of the total. It is obvious that the October and November samples contained more information than the August-September samples, probably due to summer emergence losses and the presence in August and September of very small larvae and nymphs, most of which passed through the collecting net. Mean population estimates varied from 138 m^{-2} (August) to 681 m^{-2} (October).

Regression Analyses

Multiple regression analyses were performed on the current-depth data with current and depth as independent variables and number of taxa and number of individuals as dependent variables. Three models were applied: 1) untransformed; 2) semilog transformation (of dependent variables); and 3) log-log transformation.

TABLE 8. Mean and standard deviation for four variables measured in in current-depth investigation, Yellowstone River at Glendive, 1975.

Date		Depth (ft.)	Current (f/s.)	Taxa	Indiv.
Aug. 7	Mean	1.8	1.202	3.9	9.1
	S. Dev.	0.9	0.575	1.6	8.2
Sept.17		1.2	0.744	6.5	21.7
		0.9	0.613	2.4	11.1
Oct. 9		1.4	0.786	10.9	126.9
		1.0	0.570	2.2	86.6
Nov.7		1.6	1.029	9.0	149.0
		0.9	0.678	3.8	133.9
data taken at Yellowstone River, Intake.					
Aug. 6		1.3	1.653	4.8	37.9
		0.6	0.782	1.8	32.4
Sept. 9		1.4	0.970	6.0	28.9
		1.0	0.623	1.7	12.2
Oct. 15		0.8	1.124	8.5	84.0
		0.6	1.031	2.9	53.1
Nov.11		1.6	1.477	7.0	65.8
		0.9	0.921	3.2	44.8

TABLE 9. Population estimates from the invertebrate-current samples, 24 samples from each station taken on August 6 & 7 1975. (no./m^2).

Taxa	Glendive	Intake
Baetis alexanderi	17	6
" *parvus*	34	74
Brachycercus sp.	80	17
Choroterpes sp.	0	11
Dactylobaetis sp.	11	11
Ephemerella sp.	6	0
Heptagenia sp.	57	28
Isonychia sp.	11	40
Rhithrogena sp.	11	210
Traverella sp.	193	3111
Tricorythodes minutus	63	734
Hydropsyche spp.	569	751
Leptocella sp.	28	6
Isoperla sp.	6	46
Chironomidae	119	114
Simuliidae	11	23
Dytiscidae	0	6
Oligochaeta	6	11
Totals	1222	5199
Means (Organisms/Sample)	51	217

TABLE 10. Population estimates from the invertebrate-current samples, 24 pooled samples taken Sept. 9, 1975. (no./m^2).

Taxa	Glendive	Intake
Baetis alexanderi	28	102
" *parvus*	28	108
Brachycercus sp.	34	17
Caenis sp.	6	0
Choroterpes sp.	23	57
Dactylobaetis sp.	28	97
Ephemerella sp.	0	0
Ephoron sp.	28	17
Heptagenia sp.	131	14
Isonychia sp.	0	6
Ametropus sp.	0	6
Traverella sp.	74	682
Tricorythodes minutus	279	347
" sp.	0	57
Stenonema sp.	0	6
Cheumatopsyche sp.	63	23
Hydropsyche sp.	779	1763
Leptocella sp.	0	6
Acroneuria sp.	0	6
Isoperla sp.	6	6
Microcylloepus sp.	6	0
Ranatra sp.	6	0
Ceratopogonidae	6	0
Chironomidae	1314	239
Simuliidae	6	51
Oligochaeta	119	28
Totals	2964	3638
Means (Organisms/Sample)	124	152

TABLE 11. Population estimates from the invertebrate-current samples, 24 pooled taken on October 9 & 15, 1975. (no./m^2).

Taxa	Glendive	Intake
Baetis alexanderi	1772	1490
" parvus	142	182
Brachycercus sp.	28	11
Caenis sp.	0	6
Centroptilum sp.	11	0
Choroterpes sp.	46	11
Dactylobaetis sp.	791	301
Ephemerella sp.	0	6
Heptagenia sp.	1879	943
Isonychia sp.	0	6
Rhithrogena sp.	0	742
Stenonema sp.	6	0
Traverella sp.	165	642
Tricorythodes minutus	267	91
" sp.	11	0
Unknown	6	0
Gammarus sp.	6	6
Hyalella sp.	0	6
Brachycentrus sp.	11	0
Cheumatopsyche sp.	199	51
Hydropsyche spp.	9845	4448
Hydroptila sp.	0	6
Oecetis sp.	11	0
Gomphidae	17	0
Isogenus sp.	6	80
Isoperla sp.	6	23
Corixidae	23	0
Dolochopodidae	0	6
Empididae	11	0
Chironomidae	1973	2314
Simuliidae	11	154
Stenelmis sp.	6	0
Ferrissia sp.	23	0
Lymnaea sp.	6	0
Oligochaeta	2776	1104
Totals	20,037	12,640
Means (Organisms/Sample)	835	527

TABLE 12. Population estimates from the invertebrate-current samples, 24 pooled samples taken on Nov. 7 & 11, 1975. (no./m^2).

Taxa	Glendive	Intake
Baetis alexanderi	751	392
" parvus	17	85
Brachycercus sp.	6	0
Caenis sp.	11	0
Pactylobaetis sp.	63	40
Ephemerella sp.	63	0
Heptagenia sp.	956	427
Leptophlebia sp.	6	6
Rhithrogena sp.	80	330
Stenonema sp.	11	0
Traverella sp.	51	11
Tricorythodes minutus	97	34
" sp.	6	6
Cheumatopsyche sp.	927	114
Hydropsyche spp.	10608	4846
Hyalella sp.	6	0
Brachyptera sp.	256	239
Isogenus sp.	6	142
Corixidae	46	0
Chironomidae	1905	1758
Empididae	6	0
Ceratopogonidae	0	6
Simuliidae	0	6
Dytiscidae	11	6
Ferrissia sp.	17	11
Lymnaea sp.	11	0
Oligochaeta	4374	529
Totals	20,245	8988
Means (Organisms/Samples)	844	375

TABLE 13. Population estimates and percent composition taken from the current-depth samples. Numbers are expressed in no./m^2 and the values in parentheses are percent of monthly pooled totals from the Glendive and Intake samples.

Orders	August	September	October	November	Mean
EPHEMEROPTERA	2175 (32.9)	4725 (73.6)	9555 (29.2)	3449 (11.7)	(36.9)
TRICHOPTERA	2634 (39.9)	1354 (21.1)	14,571 (44.6)	16,495 (56.3)	(40.5)
PLECOPTERA	18 (0.3)	52 (0.3)	115 (0.4)	643 (2.2)	(0.8)
DIPTERA	1616 (24.5)	267 (4.2)	4469 (13.7)	3681 (12.6)	(13.8)
OLIGOCHAETA	147 (2.2)	17 (0.3)	3880 (11.9)	4903 (16.7)	(8.0)
Others	12 (0.2)	6 (0.1)	87 (0.2)	108 (0.4)	(0.2)
Totals...	6602	6421	32,677	29,279	
Means....	138	134	681	610	
Number of samples	48	48	48	48	

It is obvious from tables 14 and 15 that depth is less frequently significant than current velocity as a means of predicting the number of taxa or the total number of individuals per sample. Number of taxa and number of individuals are similar when regressed against current velocity. Figures 5-7 are plots of the regression data showing how these data can be expressed to predict the numbers of individuals at any particular current or depth. The deviation of the data from the regression line is demonstrated in figure 7, for example, where the regression coefficients (r) are 0.774 for current and 0.808 for depth.

Mayfly diversity was large in the current-depth samples with as many as 15 species present in some. Ephemeroptera nymphs are much easier to identify to the species level, and some information was obtained on current preferences for several abundant species. These data provide some insight into niche separation in the mayfly community and how separation and current preference changes throughout the life cycle of several species.

Densities of Traverella albertana and Tricorythodes minutus are presented in figure 8. Peak densities in August at Intake for T. albertana occurred at about 2.25 feet per second (fps). Nymphs of T. albertana were more abundant in August than in any other month. This species emerges in September and October and nymphs do not reappear in any number until November.

At the Intake station during the October sampling, peak population densities were determined for several species (figure 9). Heptagenia elegantula was more abundant in slower currents and was most abundant at 0.5 fps. T. albertana was abundant near 2.5 fps as in the August samples. Baetis alexanderi was also most abundant at 2.5-3.0 fps, but there was no way to determine at what velocity this population would reach its peak. A similar situation exists with Rhithrogena undulata, although the population seems to be reaching its greatest density at about 2.75 fps. In November H. elegantula and B. alexanderi exhibited low densities at Intake, but peak densities appear to have occurred at 1.5 and 2.5 fps, respectively (figure 10).

Some current preferences were apparent for mayflies at the Glendive station (figure 11). Population extremes were evident for H. elegantula (0.5 fps), B. alexanderi (1.75 fps), and Dactylobaetis cepheus (1.75 fps). In the November samples highest densities were H. elegantula (1.75 fps) and B. alexanderi (2.0 fps) (figure 12).

All of the data on mayfly current preference were pooled and are presented in figure 13. Several trends are evident. Current preference changes with different periods in the life cycle of a species. Greatest population densities for H. elegantula changed from 0.5 fps in October to 1.5 fps in November. Populations of B. alexanderi exhibited a similar trend. The two samples of T. albertana, however, were similar (2.5 fps).

Figure 13 gives some insight into niche separation of 6 species of Ephemeroptera. Each of these species had its highest densities at slightly different current velocities, thus reducing interspecific competition for food and resting areas. The remaining mayfly species were present in numbers too small to illustrate current preference and made up an insignificant part of the fauna in the lower Yellowstone River.

TABLE 14. Synopsis of regression analysis on the current-depth data showing significance for the three models for both sampling stations. Regression of number of taxa on depth and current velocity.

MODEL	DEPTH	CURRENT VELOCITY	DEPTH AND CURRENT VEL.	DATE	STA.
I	NS	NS	NS	Aug.	17
II	NS	NS	NS	"	"
III	NS	NS	NS	"	"
I	NS	NS	NS	Sept.	"
II	NS	NS	NS	"	"
III	NS	*	*	"	"
I	NS	NS	*	Oct.	"
II	NS	NS	*	"	"
III	NS	*	**	"	"
I	**	**	**	Nov.	"
II	**	**	**	"	"
III	**	**	**	"	"
I	NS	NS	NS	Aug.	18
II	NS	NS	NS	"	"
III	NS	**	**	"	"
I	NS	NS	NS	Sept.	"
II	NS	NS	NS	"	"
III	NS	NS	NS	"	"
I	**	*	**	Oct.	"
II	**	*	**	"	"
III	**	**	**	"	"
I	*	NS	**	Nov.	"
II	*	NS	**	"	"
III	**	**	**	"	"

NS = not significant at p = .05
* = significant at p = .05
** = highly significant at p = .01

TABLE 15. Synopsis of the regression analysis on the current-depth data showing significance for the three models for both sampling stations. Regression of number of individuals on depth and current velocity.

MODEL	DEPTH	CURRENT VELOCITY	DEPTH AND CURRENT VELOCITY	DATE	STA.
I	NS	NS	NS	Aug.	17
II	NS	NS	NS	"	"
III	NS	NS	NS	"	"
I	*	*	*	Sept.	"
II	NS	NS	NS	"	"
III	*	**	**	"	"
I	**	**	**	Oct.	"
II	**	**	**	"	"
III	**	*	**	"	"
I	**	**	**	Nov.	"
II	**	**	**	"	"
III	**	*	**	"	"
I	**	*	**	Aug.	18
II	**	**	**	"	"
III	**	**	**	"	"
I	*	**	**	Sept.	"
II	**	**	**	"	"
III	*	NS	**	"	"
I	**	**	**	Oct.	"
II	**	**	**	"	"
III	**	**	**	"	"
I	**	NS	**	Nov.	"
II	**	**	**	"	"
III	**	**	**	"	"

NS = not significant at p=.05
* = significant at p =.05
** = highly significant at p =.01

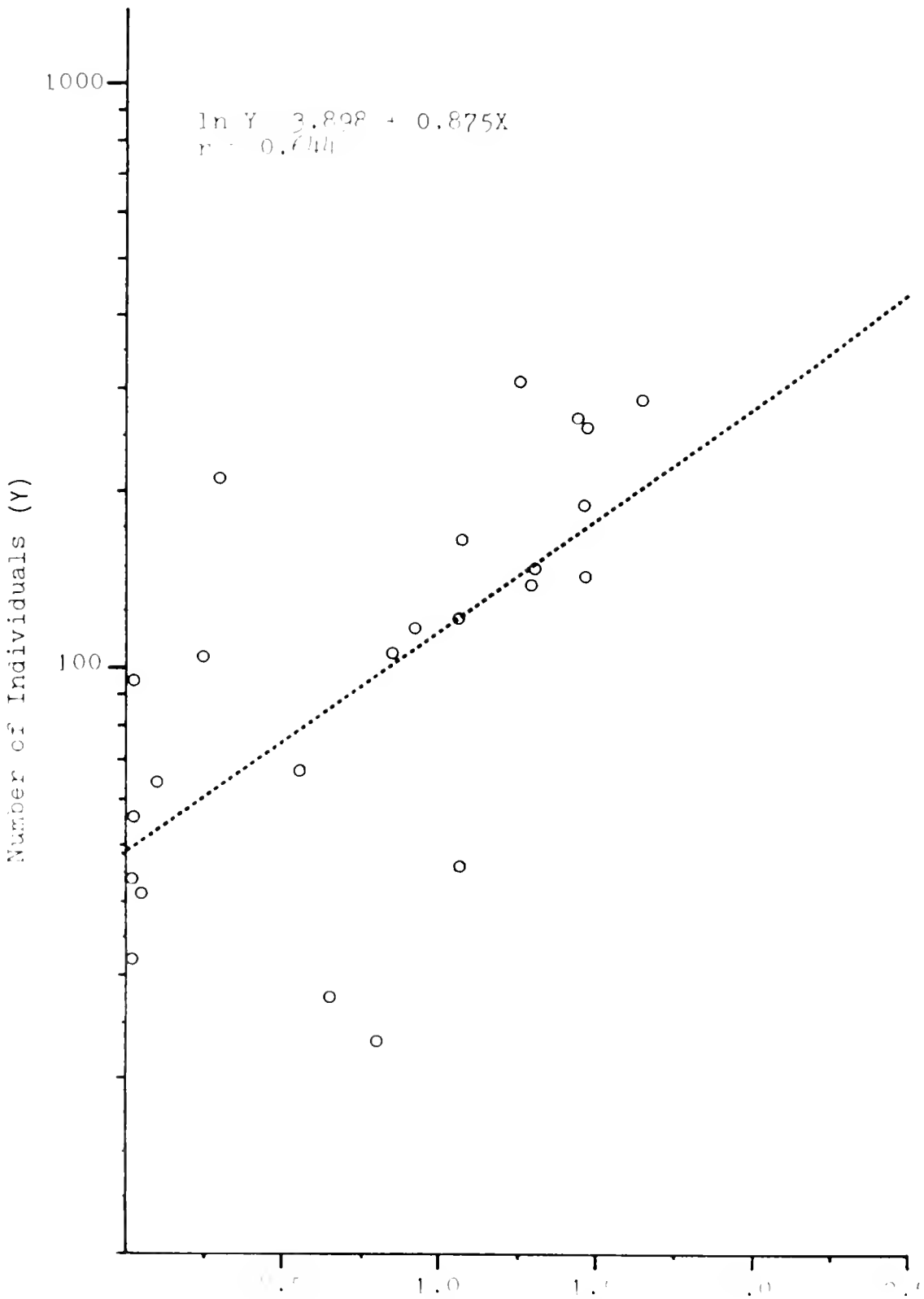


Figure 5. Current relationships, Yellowstone River, Glendive, Oct. 9, 1975.

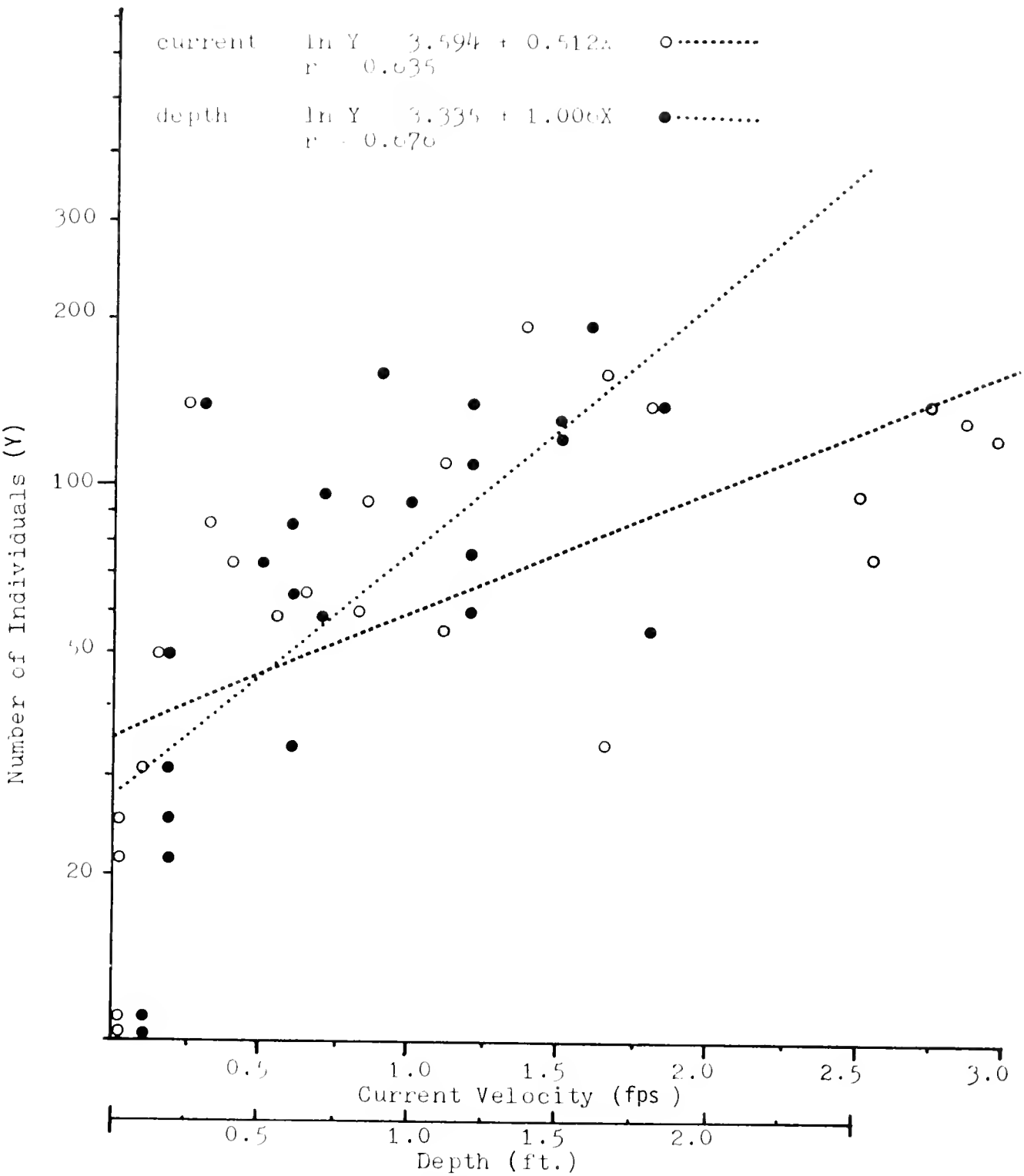


Figure 6. Current-depth relationships, Yellowstone River, Intake, Oct. 15,.1975.

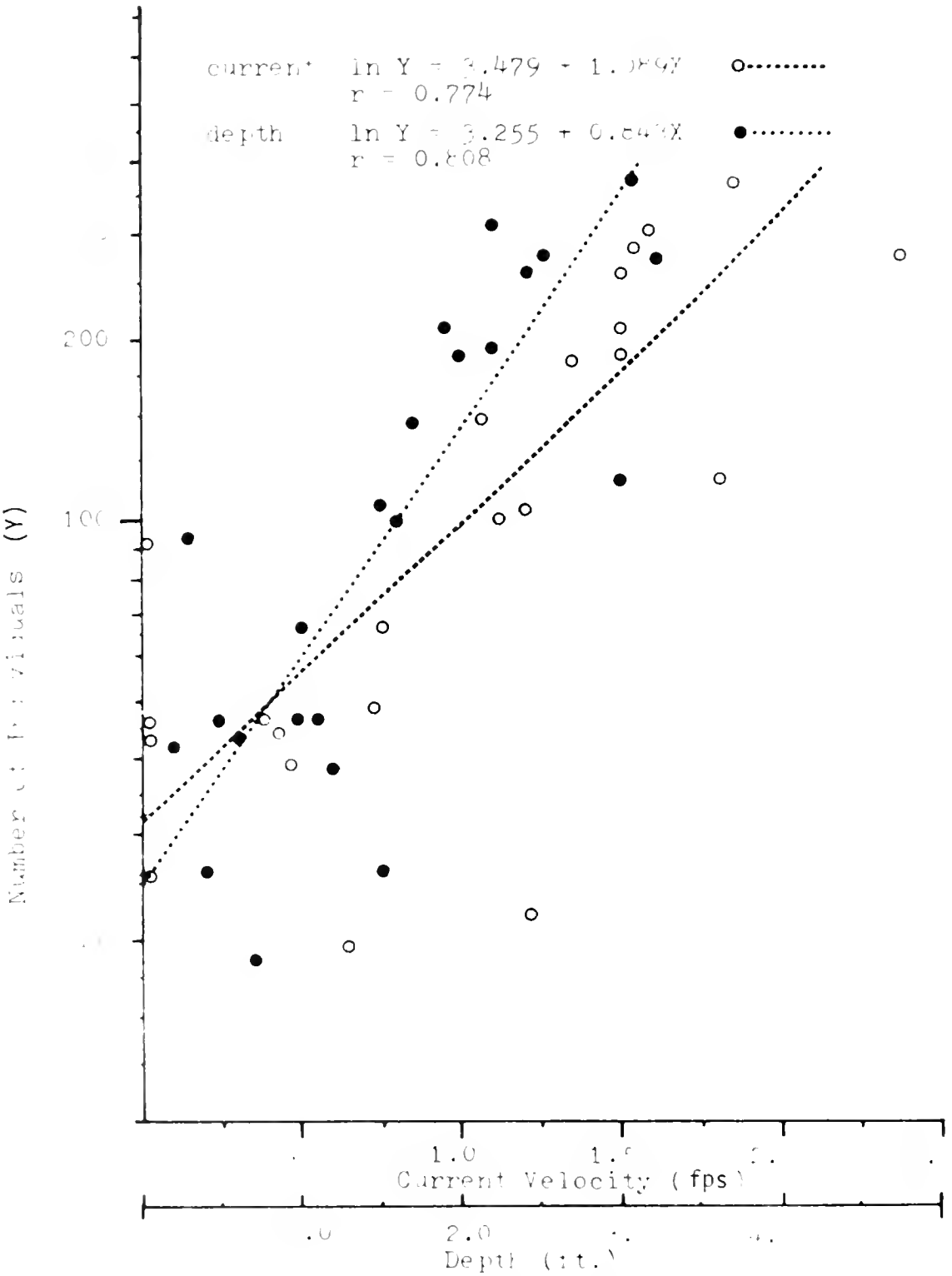


Figure 7. Current-depth relationships, Yellowstone River, Glendive, Nov. 7, 1975.

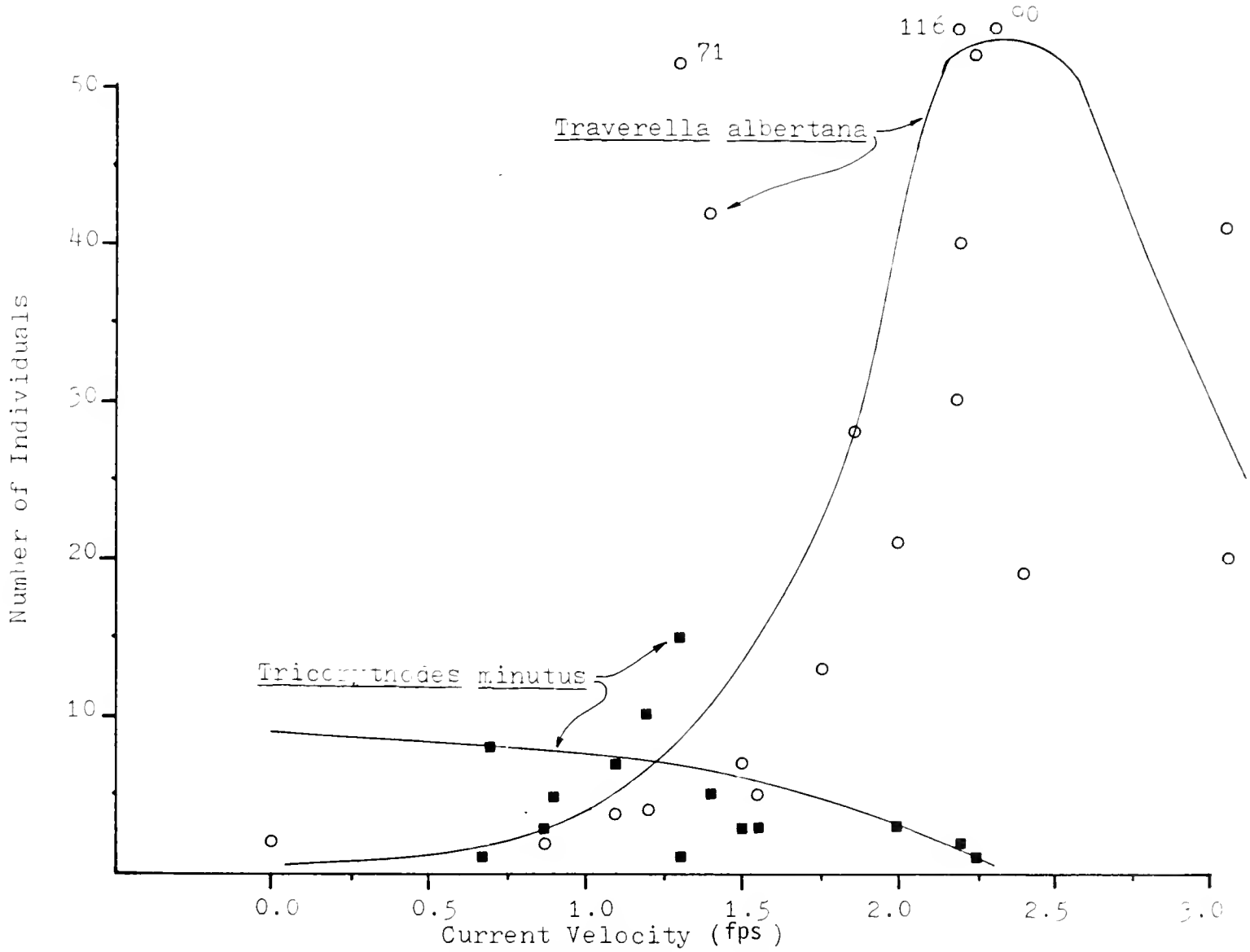


Figure 8. Mayfly distribution at various currents, Intake, Aug. 1975.

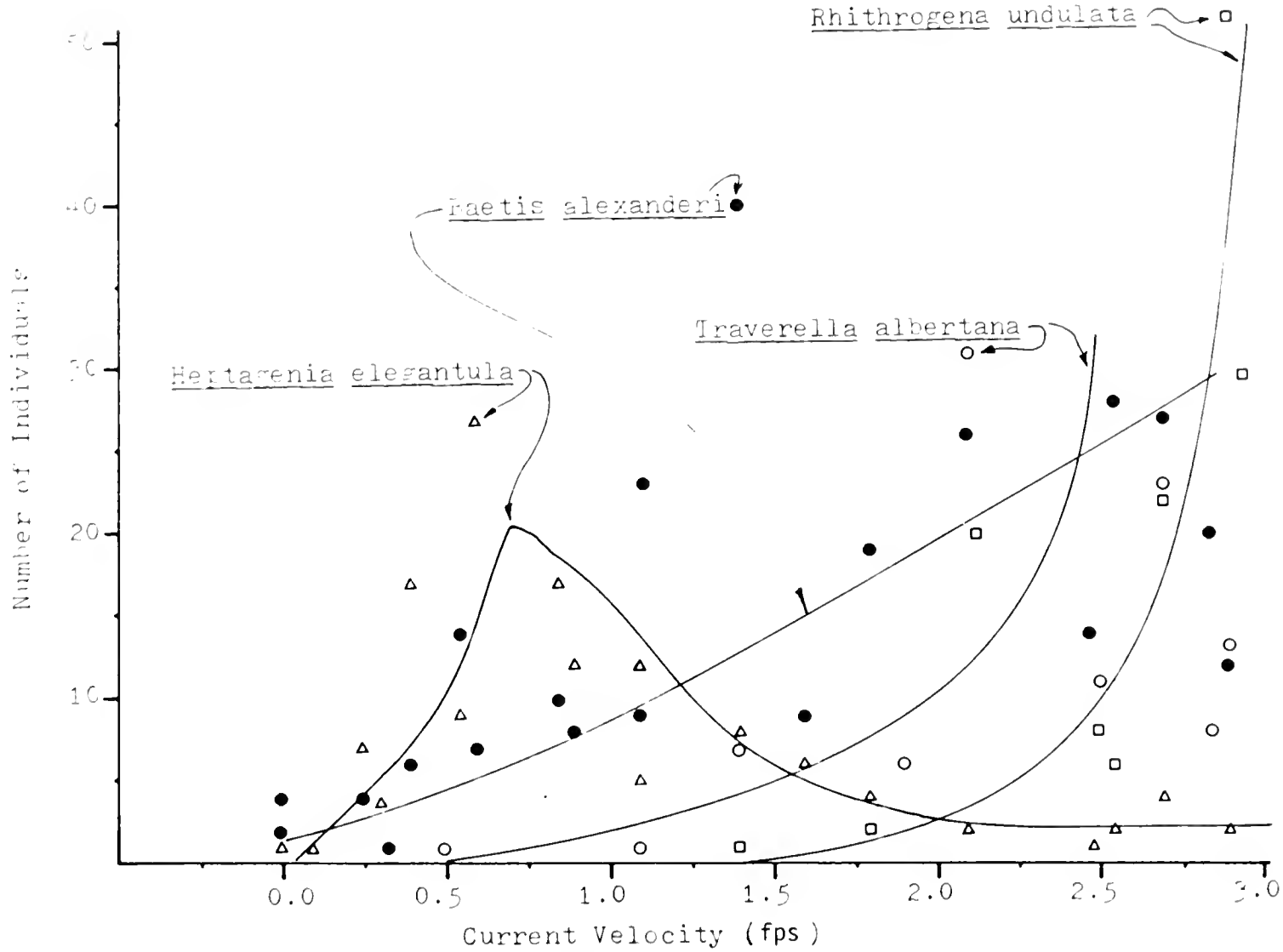


Figure 9. Mayfly distribution at various currents, Intake, Oct., 197[illegible].

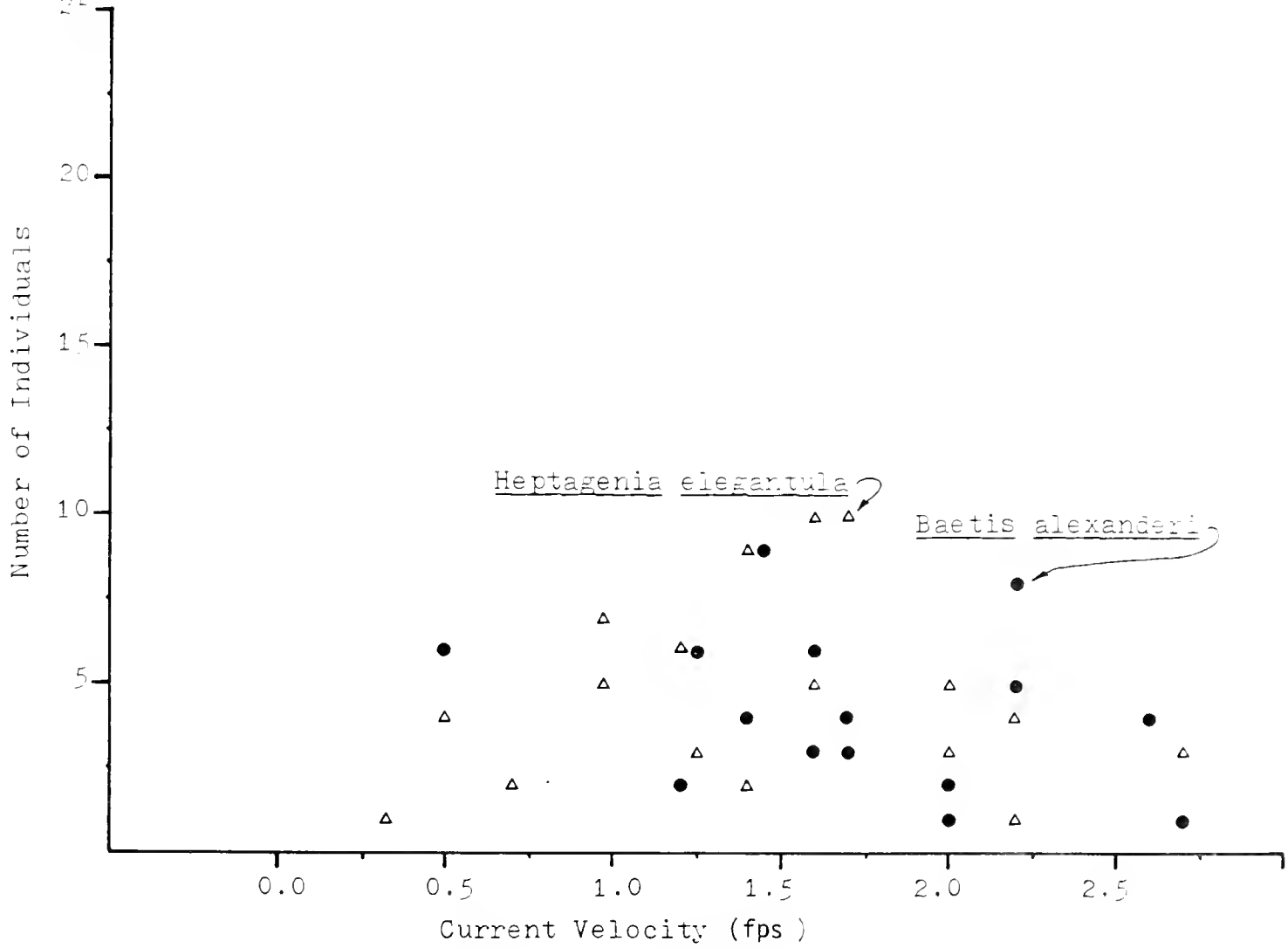


Figure 10. Mayfly distribution at various currents, Intake, Nov.197[illegible].

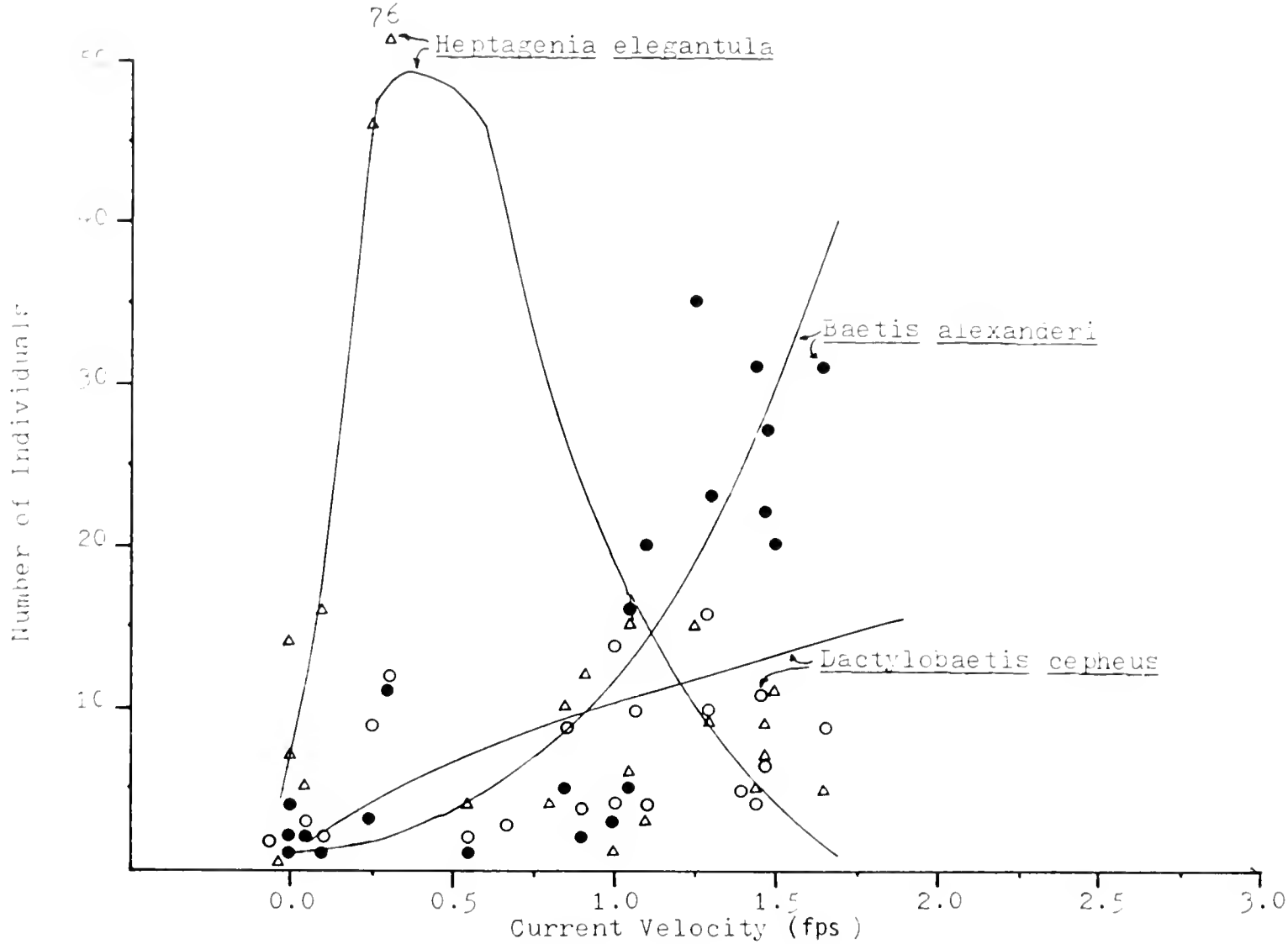


Figure 11. Mayfly distribution at various currents, Glendive, Oct.1975.

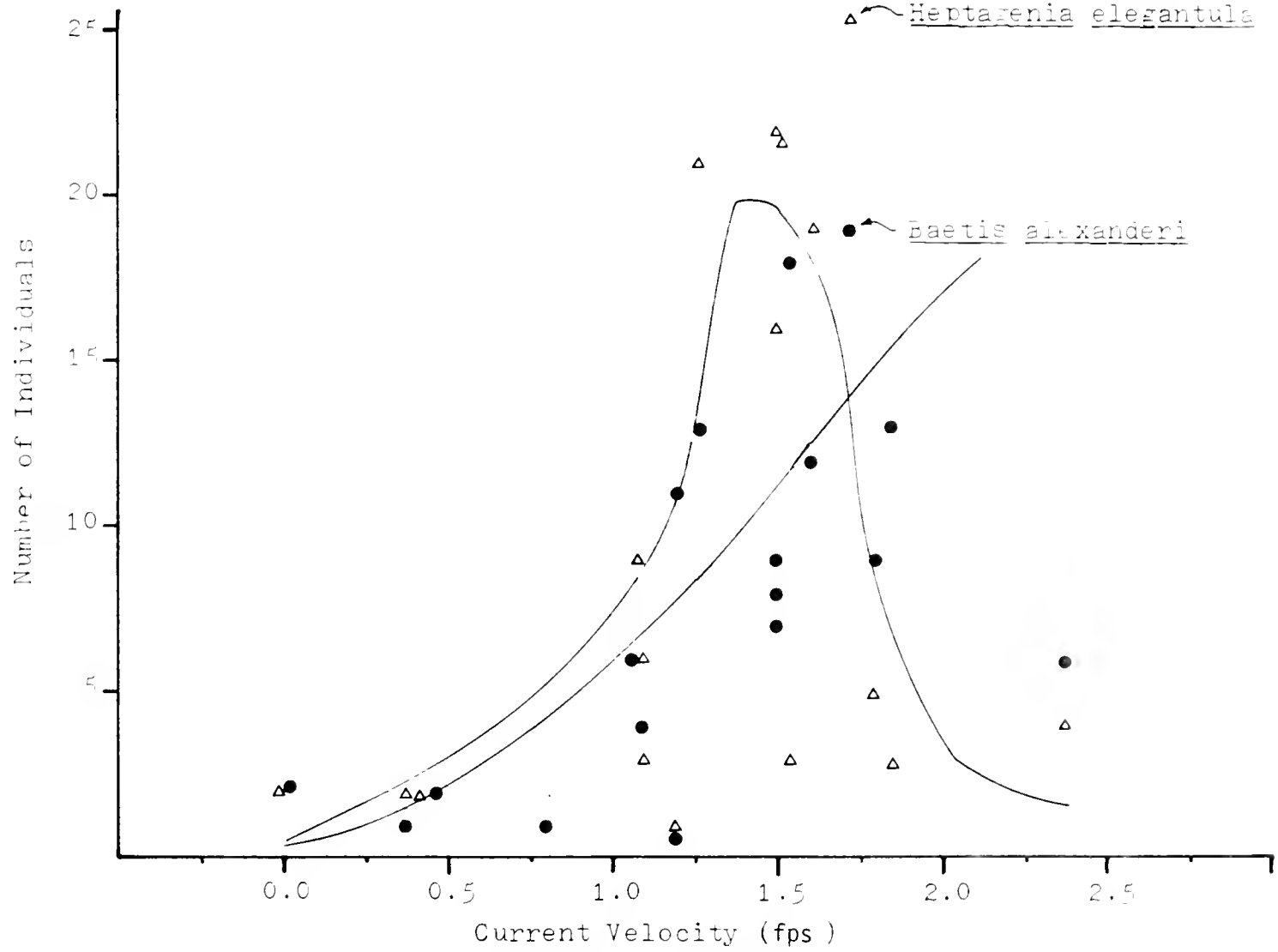


Figure 12. Mayfly distribution at various currents, Glendive, Nov. 19[illegible].

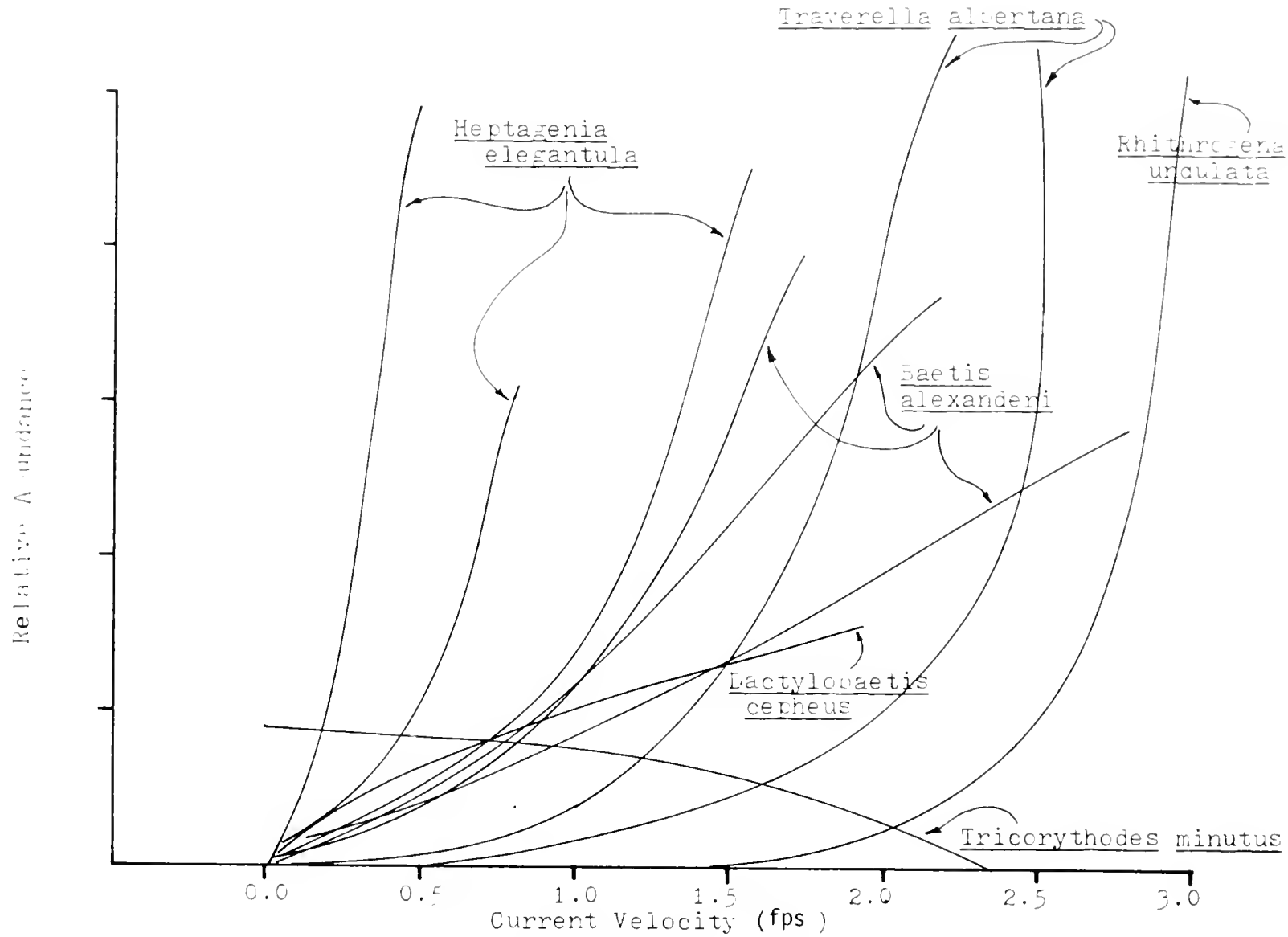


Figure 13. Synopsis of mayfly/current relationships from both stations and for all sampling months.

Plecoptera nymphs were not common in the lower Yellowstone River and little information on current preference was obtained. At Intake, however, Plecoptera were found only at the fastest currents.

Trichoptera larvae, Hydropsyche in particular, exhibited a distinct current preference with the greatest number of larvae found at the fastest currents sampled. Larvae could not be identified to species but at least 3 species of Hydropsyche have been collected at Glendive and Intake. Samples taken in August and September were not significant ($p \leq 0.05$) when relating numbers of individuals to current. Samples taken in October and November at both stations were highly significant. It is interesting to note that regression lines varied little from October to November at Glendive and at Intake (figures 14-15).

There is some evidence that Hydropsyche reached their greatest densities at about 1.5 fps at Intake in October (figure 14) and 2.0 fps in November (figure 15) after which densities decreased at greater velocities.

It is desirable to relate invertebrate densities to discharge, and this will be possible when data from the Water Surface Profile program becomes available. Discharge data above and below the study stations are shown in table 16 (U.S.G.S. 1976).

TABLE 16. Discharges at Miles City and Sidney during sampling periods, cfs.

Date	Miles City	Sidney
August 6, 1975	20,200	21,200
August 7, 1975	18,500	20,300
September 9, 1975	9,890	10,100
September 17, 1975	8,440	8,980
October 9, 1975	8,000	9,730
October 15, 1975	8,850	10,300
November 7, 1975	8,620	10,400
November 11, 1975	10,300	10,100

PRELIMINARY PREDICTION OF FLOW ALTERATION IMPACTS

It is difficult to predict the effects of flow reduction on the invertebrate fauna of a stream because of the large number of species involved and the inability to discuss the environmental requirements and tolerances of a group as large as the Ephemeroptera or Trichoptera. Even within a genus there are

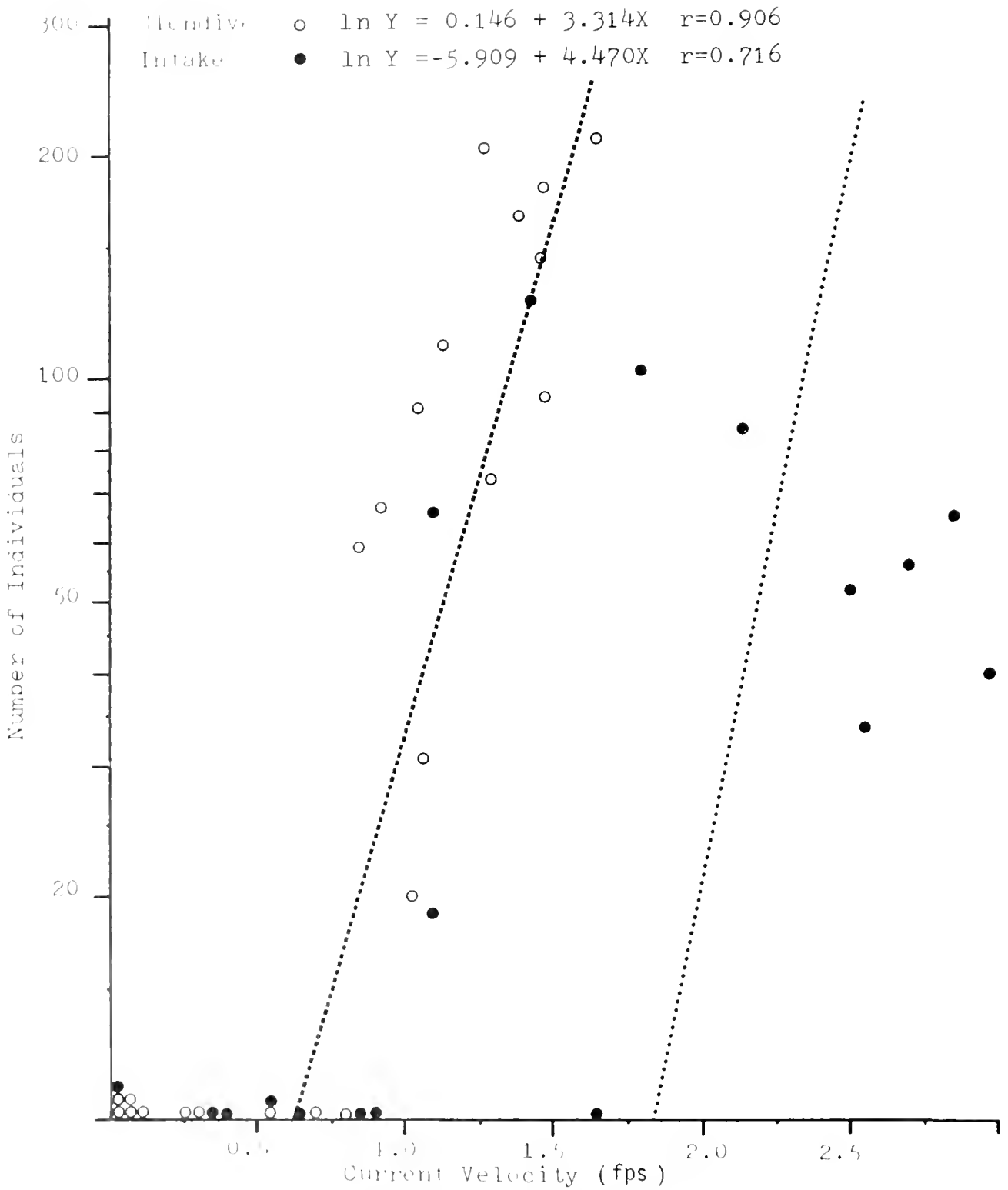


Figure 14. Distribution of Hydropsyche larvae at various currents in October 1974.

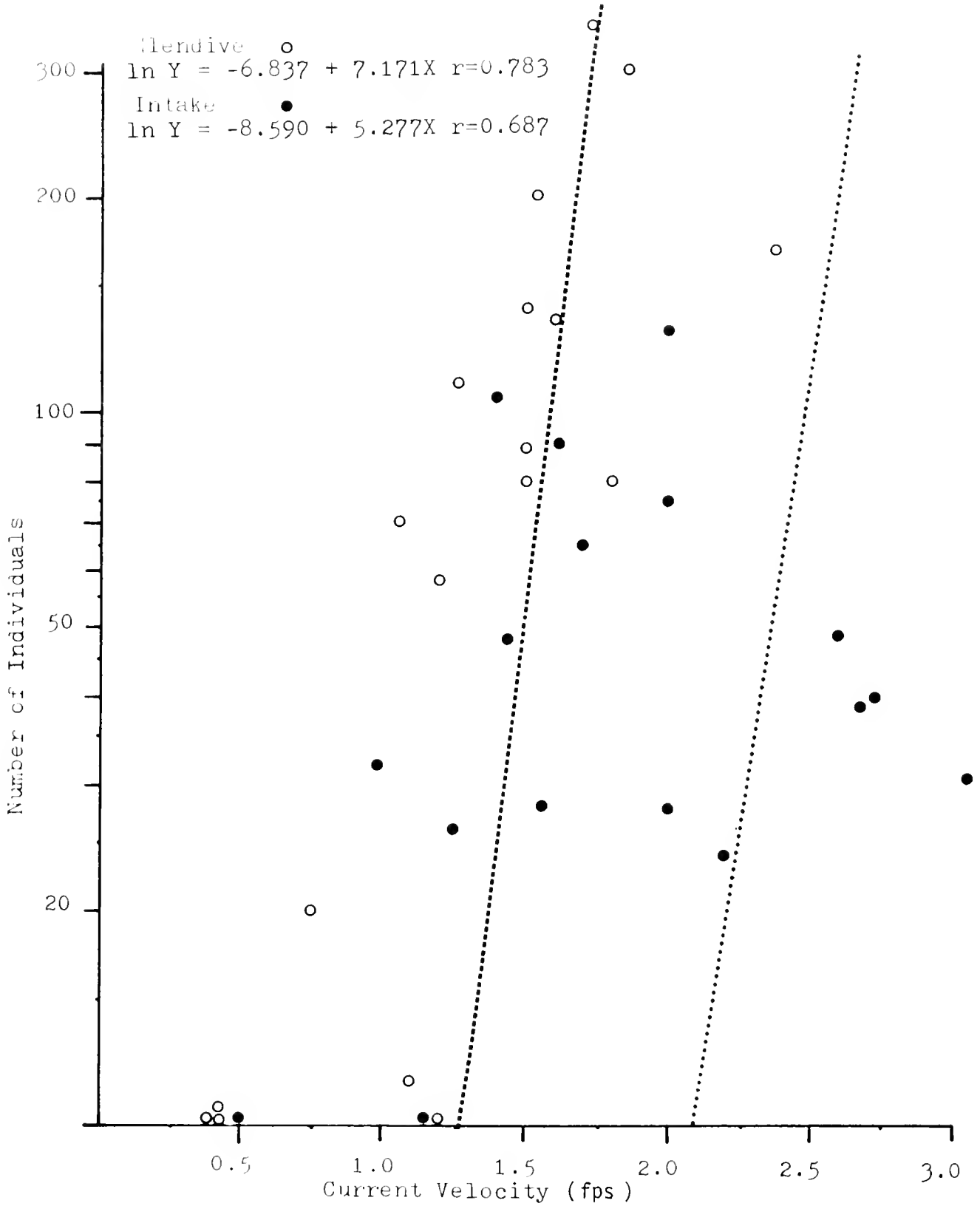


Figure 15. Distribution of Hydropsyche larvae at various currents during November 1975.

large variations in tolerance. The effort to learn the environmental requirements of a species is complicated in the west because few western species have been intensively examined. Roback (1974) lists the habitat requirements of many aquatic insects in terms of chemical concentrations but few western species are listed. Because of these problems, predictions of effects of reduced flows will be general in scope, at least at the present time.

Chemical

It is doubtful that the present or future chemical content of the river will influence the benthos of the Yellowstone River if reduced flows occur. Attempts to explain the distribution of species in terms of chemical differences have not had much success except where conditions are extreme (Macan 1974).

At present, dissolved oxygen concentrations are sufficiently high to sustain invertebrates and fish. Dissolved oxygen could influence invertebrate communities if reduced flows are so low that the BOD of domestic sewage or decaying organisms tax the reaeration capacity of the river.

With reduced flows, increased concentrations of nutrients could result in an increase in periphyton growth, especially in the present dominant alga Cladophora. A large mat of Cladophora would increase the diversity of benthic habitats and would probably result in a larger standing crop of benthic organisms, although there would probably be a shift in benthic species composition (Percival and Whitehead 1929).

Silt

Currently the Yellowstone River carries large amounts of suspended material, mostly inorganic in nature. There appears to be enough current to remove much of this material and silt deposits are not frequent along the river. The high spring runoff is one factor that keeps the river flushed of inorganic sediment. The macroinvertebrate fauna of the lower Yellowstone is predominately silt tolerant. Genera known to be silt tolerant include: Isonychia, Tricorythodes, Caenis, Traverella, Brachycercus, Stenonema, Dactylobaetis, and Ephoron (Berner 1959, Jensen 1966). It is not known how much silt the benthic fauna of the lower river can tolerate. Sampling station 20 has the lowest gradient, the greatest silt concentrations, and the lowest benthic diversity of all sampling stations. If station 20 is used as an example of what could happen at other stations if the high development scenario is achieved, the result will be a poorer fauna in numbers and species.

Temperature

Reduced flows resulting in a shallower river will probably result in higher water temperatures, which will influence the benthos. Increased temperatures would affect growth, emergence, egg hatching, dissolved oxygen, and metabolism. The net effect would probably be a reduction of the fauna.

Another factor associated with temperature is ice. In the lower Yellowstone River, a solid ice cover lasts for several months. Ice cover at Glendive lasted from late December to April during the winter of 1974-75 and late November to mid March during 1975-76. Surface ice can act in several ways to kill invertebrates (Brown et al. 1953). Low flows would permit thicker ice conditions, freezing of large areas of shallow water, and increased gouging and molar action during the time of ice break-up.

Current

Bottom samples taken at Glendive and Intake showed that invertebrate numbers are directly proportional to currents of up to 3.0 fps. No samples were taken at faster currents and, at present, predictions at faster currents are not possible. As soon as Water Surface Profile data area available, the regression equations relating numbers of invertebrates to current can be applied to the average current present in the "blocks" of water this program provides. The sum of the population estimates would provide a total population estimate for the river at any particular transect.

Flow reductions in the Yellowstone would probably create large areas of relatively slow moving water because of the morphology of the present river channel. A general reduction in flow would result in a faunal reduction because of low preference for the slower currents. Minshall and Winger (1968) found that a reduction in flow caused a large increase in invertebrate drift. Because increases in drift expose invertebrates to greater predation by fish, flow reduction may result in a loss of some sections of the stream as suitable invertebrate habitat.

Food

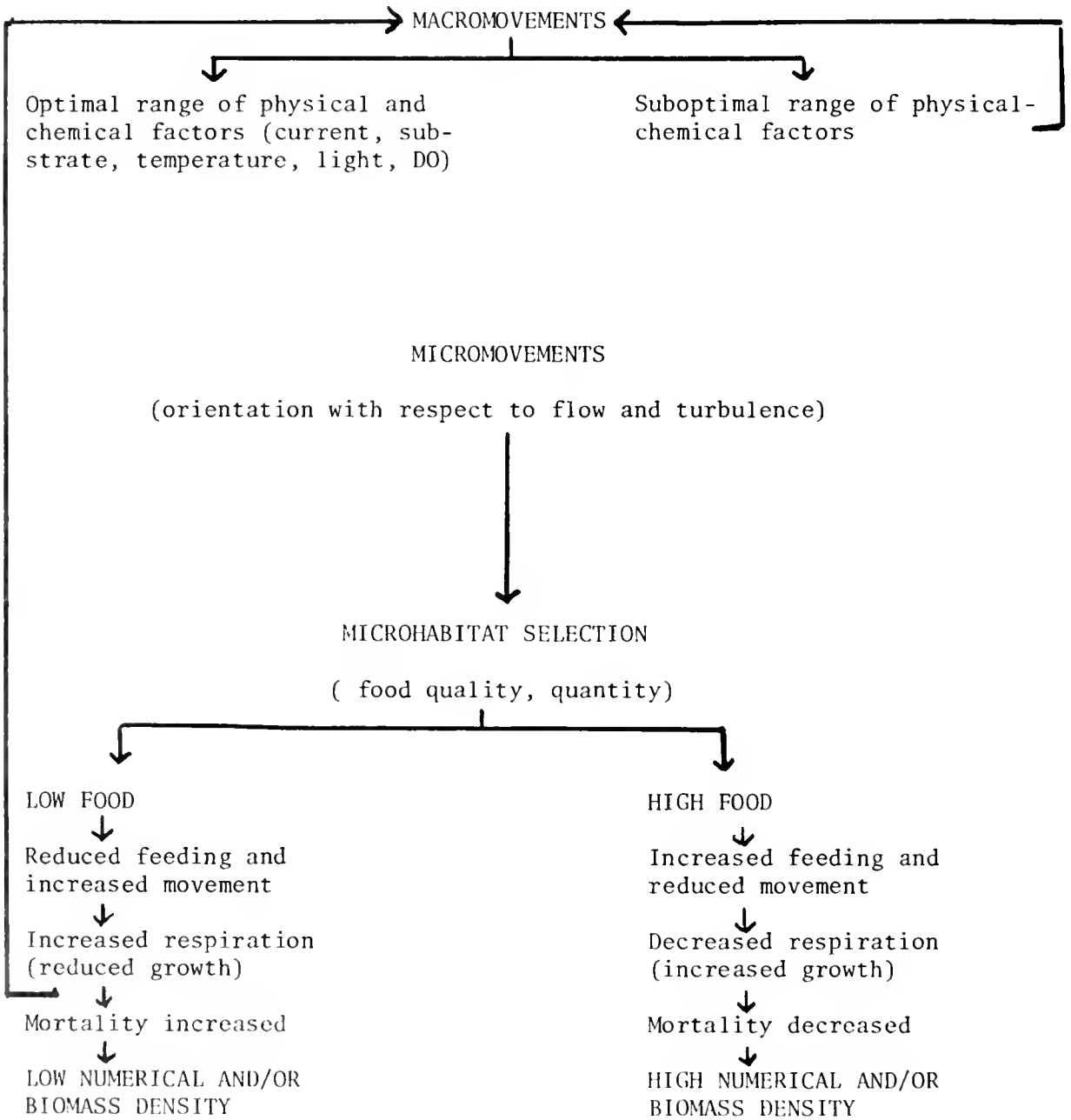
Egglishow (1964), Macan (1974), and Cummins (1975) all believe that the microdistribution of a species is more determined by food preferences than any other factor. Current distributes allochthonous detritus and periphyton, which in turn determine invertebrate distribution. Cummins (1972) presented a table on how food influences microdistribution of aquatic macroinvertebrates (table 17).

In summary, the density of the macroinvertebrate fauna of the lower Yellowstone River is directly proportional to current. This relationship is probably simplified because of the lack of diversity in the substratum. Three intimately related habitat factors influence macroinvertebrate distribution: current, substratum, and food.

ANTICIPATED ACTIVITIES NEXT QUARTER

Much of the next quarter will be spent processing quantitative bottom samples taken last fall with the Water's sampler. Six samples were taken monthly from

TABLE 17. Proposed relationships between invertebrates and the factors that determine their distribution and abundance (from Cummins 1972).



August to November, 1975, at Miles City, Glendive, Intake, and Sidney. Adult insect traps will be installed to catch adult insects to aid species identification and to gather life history data.

This phase of Task 1 is about 75% completed.

FORAGE FISH INVESTIGATIONS

Forage fish samples were collected during 1974 in the vicinities of Myers, Forsyth, Miles City, Sunday Creek, Glendive, Crane, and Sidney. The main channel and backwater areas were sampled with a 50' x 6' x 1/4" bag seine and by electrofishing. In 1975, additional samples were collected from the main channel and from backwater areas at eight locations on the lower river: Hysham, Forsyth, Miles City, the mouth of Sunday Creek, the mouth of the Powder River, Terry, Intake, and Sidney. In addition to the 50' x 6' x 1/4" bag seine and electrofishing, a 100' x 8' x 1/4" loose hung seine was utilized.

Thirty-four species were identified from the samples in 1974 and 1975. Species collected and collection sites are shown in table 18.

To determine the importance of specific forage species, food habit studies are being conducted on a variety of piscivorous species including sauger, walleye, channel catfish, burbot, and goldeye. Stomach samples have been and will continue to be taken from these species and will be examined when time permits.

TONGUE RIVER FISH STUDIES

ACTIVITIES DURING THE QUARTER

Fish Populations

Channel Catfish. Pectoral spines from 337 channel catfish--231 from the Fort Keogh (Ib) Section and 106 from the S-H (IIb) Section (see figure 3)--were sectioned as described by Marzolf (1955 (see also Sneed 1951)), using an instrument similar to the one described by Witt (1961). With this instrument the spines can be sectioned thinly enough to eliminate further grinding. The sections were coated with glycerin and aged with the aid of a binocular microscope. The translucent rings were considered to be year marks when they were distinct and continuous in all areas of the section (Marzolf 1955).

The age and growth of the 337 channel catfish were split into two sections: 1) those found below the T&Y diversion (table 19) and 2) those found between the T&Y diversion and the S-H diversion (table 20).

TABLE 18. Species list, fall 1974, Yellowstone River forage fish study.

Location and Date		Species	
Below Myers Bridge in backwater	10-30-74	Emerald Shiner	*Notropis atherinoides*
		White sucker	*Catostomus commersoni*
		Largemouth bass	*Micropterus salmoides*
		Green sunfish	*Lepomis cyanellus*
		Black crappie	*Pomoxis nigromaculatus*
		Plains minnow	*Hybognathus placitus*
		Pumpkinseed	*Lepomis gibbosus*
Below Rosebud Diversion in Main Channel	10-17-74	Emerald shiner	*Notropis atherinoides*
		Plains minnow	*Hybognathus placitus*
		Black crappie	*Pomoxis nigromaculatus*
		River carpsucker	*Carpiodes carpio*
		Shorthead redhorse	*Moxostoma macrolepidotum*
Above Miles City in Main Channel	7-25-74	Emerald shiner	*Notropis atherinoides*
		Flathead chub	*Hybopsis gracilis*
		Mountain sucker	*Catostomus platyrhynchus*
Across from Tongue in backwater	7-23-74	Plains minnow	*Hybognathus placitus*
		Emerald shiner	*Notropis atherinoides*
		Shorthead redhorse	*Moxostoma macrolepidotum*
		Bigmouth buffalo	*Ictiobus cyprinellus*
		Brassy minnow	*Hybognathus hankinsoni*
		Carp	*Cyprinus carpio*
		River carpsucker	*Carpiodes carpio*
Across from Tongue in backwater	10-23-74	Bigmouth buffalo	*Ictiobus cyprinellus*
		Smallmouth buffalo	*Ictiobus bubalus*
		Carp	*Cyprinus carpio*
		Plains minnow	*Hybognathus placitus*
Below Tongue in Main Channel	10-16-74	Mountain sucker	*Catostomus platyrhynchus*
		Longnose sucker	*Catostomus catostomus*
		Flathead chub	*Hybopsis gracilis*
		Plains minnow	*Hybognathus placitus*
		River carpsucker	*Carpiodes carpio*

TABLE 18.(continued).

Location and Date		Species	
Mouth of Sunday Creek in Backwater	9-12-74	River carpsucker	*Carpiodes carpio*
		White crappie	*Catostomus commersoni*
		Black crappie	*Pomoxis nigromaculatus*
		Sturgeon chub	*Hybopsis gelida*
	9-18-74	Sauger	*Stizostedion canadense*
		Goldeye	*Hiodon alosoides*
		River carpsucker	*Carpiodes carpio*
		Shorthead redhorse	*Moxostoma macrolepidotum*
Glendive in Backwater	10-9-74	Largemouth bass	*Micropterus salmoides*
		Sauger	*Stizostedion canadense*
		Flathead chub	*Hybopsis gracilis*
		Goldeye	*Hiodon alosoides*
		Ling	*Lota lota*
		River carpsucker	*Carpiodes carpio*
		Yellow perch	*Perca flavescens*
	10-10-74	Goldeye	*Hiodon alosoides*
		River carpsucker	*Carpiodes carpio*
		Longnose sucker	*Catostomus catostomus*
		Shorthead redhorse	*Moxostoma macrolepidotum*
		Flathead chub	*Hybopsis gracilis*
		Green sunfish	*Lepomis cyanellus*
		Drum	*Aplodinotus grunniens*
		Carp	*Cyprinus carpio*
	10-18-74	River carpsucker	*Carpiodes carpio*
		Longnose sucker	*Catostomus catostomus*
		Flathead chub	*Hybopsis gracilis*
		Emerald shiner	*Notropis atherinoides*
		Lake chub	*Couesius plumbeus*
		Shorthead redhorse	*Moxostoma macrolepidotum*
		Carp	*Cyprinus carpio*
Upstream from Seven Sisters Island in Main Channel	8-13-74	Goldeye	*Hiodon alosoides*
		Channel catfish	*Ictalurus punctatus*

TABLE 18.(continued).

Location and Date			
Across from Hysham Back-water in Main Channel	9-29-75	Flathead chub	*Hybopsis gracilis*
		Lake chub	*Couesius plumbeus*
		White sucker	*Catostomus commersoni*
		Mountain sucker	*Catostomus platyrhynchus*
Hysham Backwater	9-29-75	Carp	*Cyprinus carpio*
		Emerald Shiner	*Notropis atherinoides*
		River carpsucker	*Carpiodes carpio*
		White sucker	*Catostomus commersoni*
		Mountain sucker	*Catostomus platyrhynchus*
Below Forsyth in Main Channel	9-29-75	Emerald shiner	*Notropis atherinoides*
		Silvery minnow	*Hybognathus nuchalis*
Below Forsyth in Backwater	9-29-75	Carp	*Cyrinus carpio*
		Flathead chub	*Hybopsis gracilis*
		Emerald shiner	*Notropis atherinoides*
		Silvery minnow	*Hybognathus nuchalis*
		Fathead minnow	*Pimephales promelas*
		River carpsucker	*Carpiodes carpio*
		White sucker	*Catostomus commersoni*
		Mountain sucker	*Catostomus platyrhynchus*
		Green sunfish	*Lepomis cyanellus*
Cheyenne Island Backwater	10-1-75	Goldeye	*Hiodon alosoides*
		Carp	*Cyprinus carpio*
		Flathead chub	*Hybopsis gracilis*
		Emerald shiner	*Notropis atherinoides*
		Silvery minnow	*Hybognathus nuchalis*
		Fathead minnow	*Pimephales promelas*
		River carpsucker	*Carpiodes carpio*
		White sucker	*Catostomus commersoni*
		Green sunfish	*Lepomis cyanellus*
		Black crappie	*Pomoxis nigromaculatus*

TABLE 18.(continued).

Location and Date			
Across from and above Tongue River in Main Channel	7-24-75	Channel catfish	*Ictalurus punctatus*
		Longnose dace	*Rhinichthys cataractae*
		Flathead chub	*Hybopsis gracilis*
		Green sunfish	*Lepomis cyanellus*
Mouth of Sunday Creek in Backwater	9-10-75	Rock bass	*Ambloplites rupestris*
Across from Sunday Creek in Main Channel	8-27-75	White crappie	*Catostomus commersoni*
Below Powder River Main Channel, plus fish from puddles along side of river.	9-30-75	Flathead chub	*Hybopsis gracilis*
		Fathead minnow	*Pimephales promelas*
Below Terry in Main Channel	9-30-75	Flathead chub	*Hybopsis gracilis*
		Emerald shiner	*Notropis atherinoides*
		Silvery minnow	*Hybognathus nuchalis*
Below Terry in Backwater	9-30-75	Goldeye	*Hiodon alosoides*
		Flathead chub	*Hybopsis gracilis*
		Emerald shiner	*Notropis atherinoides*
		Sand shiner	*Notropis stramineus*
		Fathead minnow	*Pimephales promelas*
		Shorthead redhorse	*Moxostoma macrolepidotum*
		Green sunfish	*Lepomis cyanellus*
		White crappie	*Pomoxis annularis*
		Black crappie	*Pomoxis nigromaculatus*
		Sauger	*Stizostedion canadense*
Intake in Main Channel	9-18-75	Emerald shiner	*Notropis atherinoides*
		River carpsucker	*Carpiodes carpio*
		Flathead chub	*Hybopsis gracilis*
		Longnose dace	*Rhinichthys cataractae*
		Sturgeon chub	*Hybopsis gelida*
		Emerald shiner	*Notropis atherinoides*
		Flathead chub	*Hybopsis gracilis*

TABLE 18. (continued).

Location and Date			
Intake in Main Channel	8-21-75	Shorthead redhorse	*Moxostoma macrolepidotum*
		White crappie	*Catostomus commersoni*
		Goldeye	*Hiodon alosoides*
		River carpsucker	*Carpiodes carpio*
		Channel catfish	*Ictalurus punctatus*
		Plains minnow	*Hybognathus placitus*
		Sturgeon chub	*Hybopsis gelida*
		Bluegill	*Lepomis macrochirus*
		Shovelnose sturgeon	*Scaphirhynchus platorynchus*
		Sauger	*Stizostedion canadense*
		Emerald shiner	*Notropis atherinoides*
	10-3-75	Goldeye	*Hiodon alosoides*
		Finescale dace	*Phoxinus neogaeus*
		Flathead chub	*Hybopsis gracilis*
		Plains minnow	*Hybognathus placitus*
		Silvery minnow	*Hybognathus nuchalis*
		Emerald shiner	*Notropis atherinoides*
		River carpsucker	*Carpiodes carpio*
		Green sunfish	*Lepomis cyanellus*
		White crappie	*Pomoxis annularis*
Intake in Backwater	10-3-75	Flathead chub	*Hybopsis gracilis*
		Sturgeon chub	*Hybopsis gelida*
		Plains minnow	*Hybognathus placitus*
		Silvery minnow	*Hybognathus nuchalis*
		Emerald shiner	*Notropis atherinoides*
		White sucker	*Catostomus commersoni*
Sidney in Main Channel	10-3-75	Flathead chub	*Hybopsis gracilis*
		Sturgeon chub	*Hybopsis gelida*
		Fathead minnow	*Pimephales promelas*
		Silvery minnow	*Hybognathus nuchalis*
		River carpsucker	*Carpiodes carpio*
		White crappie	*Pomoxis annularis*

TABLE 18.(continued).

Location and Date			
Sidney in Main Channel	10-29-75	Goldeye	*Hiodon alosoides*
		Carp	*Cyprinus carpio*
		Flathead chub	*Hybopsis gracilis*
		Emerald shiner	*Notropis atherinoides*
		Plains minnow	*Hybognathus placitus*
		Silvery minnow	*Hybognathus nuchalis*
		Fathead minnow	*Pimephales promelas*
		River carpsucker	*Carpiodes carpio*
		Sauger	*Stizostedion canadense*
		Walleye	*Stizostedion vitreum*
	10-30-75	Sturgeon chub	*Hybopsis gelida*
		Sauger	*Stizostedion canadense*
		Shovelnose sturgeon	*Scaphirhynchus platorynchus*
		Goldeye	*Hiodon alosoides*
		White sucker	*Catostomus commersoni*
		River carpsucker	*Carpiodes carpio*
		Flathead chub	*Ybopsis gracilis*
Sidney in Backwater	10-3-75	Goldeye	*Hiodon alosoides*
		Flathead chub	*Hybopsis gracilis*
		Emerald shiner	*Notropis atherinoides*
		Silvery minnow	*Hybognathus nuchalis*
		Fathead minnow	*Pimephales promelas*
		River carpsucker	*Carpiodes carpio*
		White crappie	*Catostomus commersoni*

TABLE 19. Average length and range per age group of 231 channel catfish taken below T&Y dam on the Tongue River in the summer of 1975.

Age Group	Number of Fish	Average Length at Capture (inches)	Range of Lengths at Capture (inches)
1	2	5.0	4.4 - 5.6
2	28	8.1	7.4 - 8.7
3	9	9.0	7.9 - 10.2
4	21	10.7	8.9 - 11.9
5	17	12.5	11.0 - 14.0
6	19	13.2	11.6 - 15.0
7	6	14.7	12.5 - 17.2
8	7	15.3	13.9 - 17.2
9	22	16.3	14.1 - 23.6
10	13	17.7	14.5 - 26.8
11	16	19.1	16.2 - 21.3
12	29	20.9	17.2 - 26.0
13	24	20.9	17.1 - 26.6
14	14	22.7	18.5 - 29.6
15	3	22.6	16.0 - 26.2
19	1	29.6	29.6 - 29.6

TABLE 20. Average length and range per age group of 106 channel catfish taken between T&Y diversion and S-H diversion on the Tongue River in the summer of 1975.

Age Group	Number of Fish	Average Length at Capture (inches)	Range of Lengths at Capture (inches)
2	1	8.4	8.4 - 8.4
4	1	10.6	10.6 - 10.6
5	2	12.0	11.9 - 12.0
6	17	12.5	11.7 - 13.7
7	2	14.2	12.1 - 16.2
8	3	14.3	13.5 - 15.1
9	19	15.2	12.7 - 16.9
10	7	17.0	15.6 - 18.7
11	8	17.5	16.1 - 19.3
12	6	19.1	17.6 - 20.2
13	10	19.4	15.0 - 23.5
14	10	21.3	18.6 - 24.0
15	5	21.4	19.6 - 23.3
16	7	24.8	22.6 - 26.4
17	3	22.4	21.0 - 24.3
18	5	24.1	19.9 - 27.1

DeRoth (1965) found smaller average lengths per age class in studying the channel catfish of Lake Erie than those found here. The same held true when compared to the catfish of the Lake of the Ozarks (Marzolf 1955). Witt (1966) found a faster average growth per annulus in the Little Nemaha River. A similar growth rate was found in the Des Moines River of Iowa as reported by Carlander (1969).

The variation of lengths in a year class increased considerably at 9 years of age and greater in the Fort Keogh Section and at 13 years of age and greater in the S-H Section. The average growth per year in the Fort Keogh Section was 1.4 inches per year; in the S-H Section a pattern of strong growth every other year was established. In the "good growth" years the average growth was 1.6 inches whereas in the "bad growth" years the average growth was 0.3 inches.

Those catfish found in the S-H Section are considered a resident population since their movement is restricted by the T&Y and S-H diversions. Since growth rates were constant between years on the Fort Keogh Section, it is suggested that channel catfish may spawn every other year in the S-H Section. Meyer (1960) found through examination of annuli on paddlefish maxillary that the species spawned at intervals of 4-7 years. Thus, it is probable that the irregular growth pattern exhibited in the S-H Section by channel catfish is the result of irregular spawning activity.

Other Sportfish . Scales from the major sport species of the Tongue River collected in fall 1974 and spring and fall 1975 in the Fort Koegh (Ib), S-H (IIb), and Birney (IVb) sections were examined to evaluate age class strength and relative growth rates.

For the sample periods of fall 1974, spring 1975, and fall 1975, 67, 73, and 78 sauger scales were examined, respectively, from the Fort Keogh Section. Growth rates were similar between sample periods, averaging 2.3 inches per year based on length differences between mean lengths of age groups (table 21). This is comparable to growth rates found in the Yellowstone River by Peterman and Haddix (1975).

Ages of fish collected in the S-H (IIb) and Birney (IVb) sections are shown in tables 22 and 23. Smallmouth bass grew at an average rate of 2.6 inches per year for the two sections. The total number of age 0 smallmouth bass collected at Birney varied from 28 fish in the fall of 1974 to 4 fish in the fall of 1975. High discharges during the spring and summer of 1975 in preparation for the dam repair apparently resulted in a lower reproductive success. Reynolds (1965) suggested that water levels might be more important than temperature in initiating spawning of smallmouth bass in tributaries of the Des Moines River, Iowa. In Courtois Creek, Missouri, smallmouth bass nesting always began during a period of stable or gradually declining water levels and was delayed or interrupted some years by floods (Pflieger 1975).

TABLE 21. Average length and range of aged sauger for the fall and spring samples of 1974-1975 from the Fort Keogh Section on the Tongue River.

Time	Age at Capture	Number	Average Length at Capture (inches)	Range of Lengths at Capture (inches)
Fall 1974	1	1	11.2	11.2
	2	14	12.6	10.8 - 13.5
	3	23	14.1	13.3 - 15.9
	4	24	15.3	14.1 - 16.5
	5	3	17.3	16.7 - 18.0
	6	1	23.0	23.0
	7	1	25.3	25.3
Spring 1975	2	2	10.9	10.8 - 11.0
	3	14	12.5	10.0 - 14.8
	4	21	15.0	12.9 - 17.4
	5	31	16.4	14.5 - 18.9
	6	4	19.0	18.4 - 20.3
	7	1	16.2	16.2
Fall 1975	1	5	9.4	8.4 - 10.8
	2	29	12.4	10.0 - 14.3
	3	24	14.3	12.8 - 16.2
	4	16	16.0	14.4 - 19.0
	5	4	19.3	17.5 - 22.0

TABLE 22. Average length and range of aged sport fish for the fall samples of 1975 from the S-H Section on the Tongue River.

Species	Age at Capture	Number	Average Length at Capture	Range of Lengths at Capture
Smallmouth bass	1	10	6.2	5.1 - 7.4
	2	5	8.8	7.9 - 9.6
	3	4	12.7	11.6 - 13.9
	4	4	14.1	12.9 - 15.3
Rock bass	1	1	2.2	2.2 - 2.2
	2	1	4.1	4.1 - 4.1
	3	2	6.0	5.4 - 6.5
	4	1	7.4	7.4 - 7.4

TABLE 23. Average length and range of aged sport fish for the fall samples of 1974 and 1975 from the Birney Section on the Tongue River.

Species		Age at Capture	Number	Average Length at Capture	Range of Lengths at Capture
Smallmouth bass	Fall '74	0	28	3.3	2.6 - 6.0
		1	28	6.4	5.4 - 7.7
		2	9	8.7	8.4 - 9.1
		3	8	10.8	9.9 - 12.3
		4	2	12.8	12.3 - 13.2
	Fall '75	0	4	4.5	3.9 - 4.8
		1	36	5.5	4.9 - 6.8
		2	9	8.4	6.0 - 11.0
		3	5	11.8	10.4 - 14.3
		4	1	15.1	15.1 - 15.1
Rock bass	Fall '74	1	9	3.9	3.0 - 4.3
		2	14	5.0	4.3 - 6.0
		3	14	6.3	5.7 - 6.9
		4	4	7.3	7.1 - 7.6
		5	3	8.4	7.9 - 8.9
	Fall '75	1	6	2.8	2.3 - 3.5
		2	20	4.0	3.3 - 4.7
		3	31	5.6	4.7 - 6.8
		4	17	6.7	5.4 - 8.0
		5	2	7.8	7.5 - 8.0

PRELIMINARY IMPACTS

Tongue River

Preliminary impacts of Tongue River flows resulting from the four scenarios were assessed by flow period. The year was divided into four segments which correspond to life history phases of the important fish species in the Tongue River. Bovee (1975) proposed an instream flow methodology for prairie streams which recognizes three basic biological phases in the life history of fish: migration, spawning, and rearing. The breakdown on the Tongue River analysis follows this scheme but considers over-winter flows as well.

The fall flow period encompassed the months of August through November. These are critical flows for fish, since this period of low flow accompanied by warm water temperatures is the rearing period. For successful rearing of stream fishes, an adequate food base must be consistently available and micro-habitat and water quality requirements of the species must be met. A reduction in flow at this time would possibly elevate water temperatures above tolerable limits.

The months of December and January constituted the winter period. These months are important to sustain the populations during a critical low flow period with reduced oxygen levels. At this time population levels are reduced to make room for recruitment. This is also a rearing phase in the life history of stream fishes. Little is known about flow needs during this period.

Spring (March through May) corresponds with the migration and spawning seasons of most important warm-water species. If adequate flows are maintained to insure passage, it is assumed that adequate water would also be available for spawning and rearing.

The peak run-off period of May through July is also important for passage, spawning, and rearing. Additionally, spring peaks scour the channel, cleaning the interstices for food production and successful reproduction.

Habitat requirements of all fish, wildlife, and other aquatic organisms have, through the long evolutionary process, come to be dependent upon the natural flow regimen of a river system. Fish production in rivers depends upon the maintenance of spawning and rearing areas, sufficient shelter, adequate food supply, and water quality. The stream discharge, as influenced by channel configuration, must meet the hydrologic requirements necessary to provide these factors.

Scenarios. A summary of possible impacts associated with each scenario is presented in table 24.

No major impact associated with the low scenario could be predicted to occur on the Tongue River.

Impacts predicted for the intermediate scenario were greatest during the spring season, when an estimated 5.4 million square feet of potential spawning habitat would be lost downstream from the T&Y diversion. Winter flows less than 90 cfs result in icing on riffles and, therefore, invertebrate losses (Bovee 1976). This would occur about 20 percent of the time with this flow level. These flow levels would adversely impact the fishery.

The intermediate scenario with 60 percent of NGPRP instream flows (NGPRP 1974) was judged to have high impact. In many years there would be little or no flow in the river during the fall and riffles would freeze during the winter. Approximately 7 million square feet of potential spawning habitat would be lost during the spring downstream from the T&Y diversion. During the run-off period, no flow would be present about one-third of the time. Paddlefish would be unable to migrate upstream about one-fourth of the years in which there would be measurable flow. With these flow levels, there would be minimal fishery downstream from the T&Y diversion.

With the high scenario, flows would be almost nonexistent downstream from the T&Y diversion, and impacts would be extreme.

Since that portion of river downstream from the T&Y diversion provides a spawning and nursery area for fish from the Yellowstone River, a reduction in

TABLE 24. Predicted impacts of flow scenarios on the Tongue River.

Season	Low	Intermediate	Intermediate (60% NGPRP)	High
Fall	Little impact, possible high temp. during Oct (2.5% of the time).	Possible impact: 1 out of 8 years, no flow; 1 out of 2 years, possible high temps.	High impact: 1 out of 3 years no flow; 91.7% of the time, possible problem with high temps.	Extreme impact: 98.3% of the time, no flow, remainder of flows inadequate to support fishery.
Winter	No impact other than those occurring naturally.	Possible impact: 2 out of 9 years, ice would form on riffles, with possible O_2 depletion.	High impact 4 of 5 years riffles would freeze, with probable O_2 depletion.	Extreme impact: 94.4% of the time, no flow; 2.2% of time with adequate flows.
Spring	No impact other than normally occurring	Possible impact: 4 out of 10 years, spawning habitat reduced; 1 out of 10 years, inadequate flows; and 1 out of 30 years, no flow.	Possible impact: 3.3% of time, no flow; spawning habitat reduced greatly all years.	High impact: 68.8% of the time, no flow; remaining years flows inadequate and spawning habitat lost.
Run-off	No impact other than normally occurring	Possible impact: 1 out of 4 years, no bedload movement, loss of scouring 30% of time no flow; some possible high temp. problems.	High impact: 31.7% of time, no flow; 27.8% of the time, flow inadequate for paddlefish spawning, high temp. problems possible also.	Extreme impact: 61.7% of the time, no flow; 18.3% of the time, flows would be inadequate.

flows would also impact the Yellowstone River fish population. Thus, these impacts can only be assessed by considering impacts on the Yellowstone River as well as on the Tongue River.

Tongue River Reservoir

Impacts of the scenarios on the Tongue River Reservoir (low scenario) or the New Tongue River Reservoir (intermediate and high scenarios) were evaluated based on storage patterns associated with water releases. Major sport fishes in the Tongue River Reservoir spawn during April and May and depend on stable or rising water levels during this period. A decreasing level would result in a loss of available spawning habitat and would desiccate incubating fish eggs. Storage patterns predicted by the scenarios were judged detrimental if the reservoir level decreased from April through May.

With the low scenario, only one year out of 29 resulted in poor reproductive potential. The intermediate scenario showed 6 years out of 29 with poor spawning potential while the intermediate scenario with 60 percent NGPRP instream flows resulted in 4 years of poor spawning potential. With the high scenario, storage patterns resulted in poor reproductive potential 10 years. This is an average of one year out of three with the possibility of reduced spawning.

Impacts on the fishery of the Tongue River Reservoir were judged to be relatively small. Even with poor reproduction every three years, a substantial fishery should result from the remaining years' reproduction.

ACTIVITIES PLANNED FOR NEXT QUARTER

In the Tongue River, runs of shovelnose sturgeon and sauger will be monitored to evaluate passage and spawning flows. Physical parameters will be measured at the primary sections.

At the Tongue River Reservoir game fish populations will be monitored and the creel census will be reactivated.

This phase of Task 1 is about 70% completed.

TASK 2. ASSESSMENT OF THE IMPACT OF ALTERED STREAM FLOWS ON SELECTED MIGRATORY BIRDS. The Grantee shall make a complete analysis of the structure and vegetation of the Yellowstone River from Big Timber to the North Dakota border, with major emphasis being placed upon the islands. The Grantee shall determine the importance of the river system, and altered stream flows, to migratory birds, including but not limited to geese, ducks, bald eagles, and great blue herons. The Grantee shall assess the ecological productivity and importance of this river system from a regional perspective.

QUARTERLY ACTIVITIES

CANADA GOOSE STUDIES

Goose censuses along the lower Yellowstone River during the quarter reflected the presence of spring migrants as shown in table 25. Had the March census been conducted one week earlier, the goose count would probably have approached that obtained in early April, 1975. Field-feeding observations recorded on March 8 and 9, 1976, indicated that, despite warm temperatures and clear skies, spring migrants stopped in the valley in as large numbers as in 1975.

The 1976 wintering goose population was as small as in 1975, although some ingress appeared to occur from January to February when temperatures moderated. (Temperatures at Miles City were below 0^{o} F on eight days in January and on one day in February according to F.A.A. records. The mean maximum temperature for January was 28^{o} F while that for February was 42^{o} F.) The January census which yielded 131 goose observations was conducted when the air temperature was approximately -10^{o} F, and most geese in the study area were loafing along the ice shelf-water interface along the river upstream from Forsyth.

TABLE 25. Aerial censuses of migratory birds conducted along the Yellowstone River between Billings and Fairview, Montana, between January 1 and March 31, 1976.

Date	Canada Geese	Dabbling Ducks	Common Goldeneyes	Common Mergansers	Adult Bald Eagles	Immature Bald Eagles
January 1 & 7	131	3,339	445	110	34	9
February 9 & 10	480	13,227	1,835	334	29	9
March 18 & 19	3,831	14,953	454	373	85	35

Observations of geese in the Hysham-Myers section in February produced one observation of a goose neck-banded in that area on July 2, 1975. More observations of this type are needed before it can be determined if many resident birds are present in this section in the winter or all year.

March field observations in the Sanders-Hysham section produced sightings of geese neck-banded by other researchers. As in the spring of 1975, geese were observed in this area which are believed to have been released in Alberta by Ducks Unlimited. The sightings were reported to the Bird Banding Laboratory in Patuxent, Maryland, in hopes of obtaining the banding data. All observations of yellow neck-banded birds occurred in the Myers-Sanders section. This may indicate a specific migration corridor through this area used by northerly-breeding geese. This corridor may account for the consistently high numbers of geese observed in this area during migration periods.

Six resident geese neck-banded in 1975 were observed in March, 1976. Half were adult females with a mate returning to their breeding grounds to nest. No groups of non-breeding age birds (juveniles banded in 1975) were observed. Neck band loss or high mortality of neck-banded geese may account for the paucity of these observations.

Observations on the Yellowstone and Bighorn rivers in early February showed some geese already segregated into pairs. Field-feeding in hayfields and pastures was observed but feeding on riparian vegetation along the Bighorn River also appeared to be common.

DABBLING DUCK STUDIES

Dabbling ducks present in the study area during the quarter were censused on three occasions as shown in table 25. The January census reflected the lowest wintering level, after which movement of field-feeding flocks into the valley occurred in the warmer month of February. The March census reflected, at least to some extent, the northward migrations of early spring migrants. Pintails (Anas acuta), blue-winged teal (Anas discors discors), green-winged teal (Anas crecca carolinensis), northern shovelers (Anas clypeata), baldpates (Anas americana), and gadwalls (Anas strepera) were present at that time.

Field observations of ducks during this quarter in the lower Yellowstone and Bighorn river valleys reflected duck preference for feeding in cornfields such as was observed in late fall.

BALD EAGLE STUDIES

Table 25 lists the results of eagle censuses conducted this quarter. The March total shows the increase in both adult and immature birds in the study area during spring migration. Both January and February counts reflected the comparatively lower wintering population.

Two wing-tagged eagles were seen during the quarter by other observers. The red-and-yellow tags were placed on the birds by Jon Gerrard of Minneapolis in his breeding-ground research in the lake country of central Saskatchewan. Correspondence is forthcoming from him regarding approximate banding location of each bird.

OTHER QUARTERLY ACTIVITIES

Aerial photographs of the lower Yellowstone from Billings to Miles City were studied to classify riparian vegetation on river banks and islands. The overlays of this river section were then sent to Bozeman to be analyzed on a digitized planimeter. Key nesting islands discovered in 1975 were checked periodically to follow the progress of goose nesting efforts.

PRELIMINARY IMPACTS OF WATER WITHDRAWALS ON MIGRATORY BIRDS

MID-YELLOWSTONE HIGH SCENARIO

Future water withdrawals from the lower Yellowstone River will impact the migratory bird populations in two basic ways: 1) by changing land use and agricultural patterns in the river bottom, and 2) by changing the channel morphology, water levels and flows, and other features of the river itself. The interrelationships of these changes and the resultant impact on the bird populations may be beneficial or detrimental to the bird populations depending on the timing and location of the water diversions.

Under the high scenario the irrigated acreage in the lower part of the valley is expected to increase by 84,000 acres, greatly increasing the number of possible field-feeding areas for waterfowl, especially if many of the new fields were planted to corn and barley and irrigated by center pivot irrigation systems. If located largely between Pompey's Pillar and Rosebud, these large fields could induce migrant waterfowl to stop longer in this section than they do now, thereby increasing the number of dabbling ducks and geese present in the spring and fall.

An increase in irrigated acreage in the Yellowstone Valley would be accompanied by a similar increase in farming activity. This increased activity would probably have little effect on the migrant and resident fish-eating birds unless it included clearing of cottonwoods which could destroy roost and rookery trees, reduce bank stability, and ultimately alter the stream channel. This increased activity would also probably detract from the river's attractiveness to bald eagles by destroying roost trees and reducing isolation on the river bottom, adversely affecting eagle behavior and their use of an area.

The high level of water development on this part of the river will produce regulated flows which may impact migratory birds according to the following pattern. The regulated flows during the high water period (approximately 1,500 to 2,000 cfs below historic peak flows) would probably have little effect

on the migratory birds under consideration since the regulated peak flows would still be sufficient to flood most of the river bottom in high run-off years, maintaining the open aspect of bars and island edges and continually setting back plant succession in those areas. The regulated late-summer flows (approximately 2,000 cfs below historic low flows) would increase the surface area of open, unvegetated bars and islands which at that time serve as secure loafing areas for free-flying ducks and geese. In some sections of the river, Canada geese historically loafed on lateral bars of the main banks because of a lack of nearby open, island loafing sites. Regulated late-summer flows will probably produce more exposed midstream bars and widen already existing lateral bars, thereby keeping loafing birds away from bank vegetation and other predator cover.

If regulated, late-summer flows increase stagnation of backwater areas, dabbling duck brood habitat, i.e. areas producing aquatic plants and invertebrates, would also increase. Low, late-summer flows causing fish concentrations could also increase feeding success of fish-eating birds. This fish confinement would be beneficial to these birds only for short periods, as prolonged reduction of the water flow could ultimately decrease fish numbers. Low, late-summer flows would not likely affect the bald eagle population as eagles are absent in the area in late summer, and the aftereffects of such flows would be small providing the low flows lasted for only a short time.

MID-YELLOWSTONE INTERMEDIATE SCENARIO

As with the high scenario, the impact of this level of water development on migratory birds includes the increase in the size, diversity, and number of fields available to field-feeding ducks and geese. This increase could encourage increased use of the river by migrant populations and possibly result in higher breeding populations. The effects of increased farming activity and irrigated acreage on migratory birds other than waterfowl would be similar to those mentioned in the high scenario section, but probably of lesser extent. The difference between regulated and historic flows, the second aspect of possible impacts on migratory birds, is small and probably would have little effect on any of the migratory birds in question.

MID-YELLOWSTONE LOW SCENARIO

The increase in irrigated acreage associated with this level of water development is small and probably would not noticeably affect field use by waterfowl populations. Similarly, the effects of this minor increase in farming activity along the river on the migratory birds would probably be negligible. The regulated flows resulting from this level of water use are not sufficiently different from historic flows to appreciably affect migratory bird use of the river itself.

BIGHORN RIVER HIGH SCENARIO

Because of the regulated nature of the flow of this river since 1966, further water withdrawals under this level of development could have a marked impact on the ecology of large migratory birds in the Bighorn Valley. This is true both of the lowest summer flows and the reduced peak flows.

Reduced flows from April through September would be detrimental to Canada geese and island-nesting ducks if they resulted in the loss of island and bar integrity during the breeding season. By late summer, the security of already-scarce loafing sites would be reduced because of increased predator cover and reduced interisland channel depths resulting from lower water levels. However, these low flows could increase feeding areas for dabbling duck broods along the river if stagnant backwaters became more plentiful and could also concentrate fish, possibly attracting fish-eating birds. However, reduced flows for the five-month period from April to September could be detrimental to fish populations because of the prolonged reduction in fish habitat. The low flows would probably not affect bald eagles to a great extent for two reasons: eagles are not common in the area from April through September; and they probably are not dependent on fish as a major source of food.

Under the high scenario there would be an increase of 102,382 irrigated acres in the Bighorn Valley. Should this occur, the valley would probably continue to attract an increasing number of migrant field-feeding waterfowl. The large concentrations which occur in the valley now in fall and spring might be induced to winter there. This could increase winter mortality of these populations during periods of extremely cold and snowy weather.

The possible impacts of increased farming activity along the river on piscivorous birds and goldeneyes are difficult to determine. Generally, further opening-up and alteration of the river bottom could be detrimental to these birds. Increased farming would greatly detract from the Bighorn's attractiveness to bald eagles through loss of isolation of many parts of the river bottom. Numbers of eagles using the river could decline unless they became accustomed to human disturbances around roosts and feeding areas.

BIGHORN RIVER INTERMEDIATE SCENARIO

The impacts of increased irrigated acreage associated with this level of water development could be similar to those of the high scenario but lesser in extent. The impact of further flow reduction may be small owing to the comparatively greater regulation which has occurred since 1966, the ample bird populations present since the 1966 flow alterations, and the small additional difference between the proposed regulated and post-1966 historic flows.

BIGHORN RIVER LOW SCENARIO

The small increase in irrigated acreage would produce a similarly small increase in the attractiveness of the valley to field-feeding waterfowl. The

regulated flows are not divergent enough from the historic flows to produce a marked impact on migratory birds.

ACTIVITIES PLANNED NEXT QUARTER

During the upcoming quarter projects planned include: the second year of the goose nesting study, continued aerial censuses, heron rookery counts, and the beginning of goose trapping, banding, and web-tagging.

To date Task 2 is approximately 70% completed.

TASK 3. ASSESSMENT OF THE IMPACT OF ALTERED STREAM FLOWS ON SELECTED FURBEARING MAMMALS. The Grantee shall inventory furbearing mammals along the Yellowstone River from Big Timber to the North Dakota border and determine their relative abundance. The Grantee shall identify the habitat types most important to selected species, including, but not limited to, beaver, muskrat, mink and river otter, and assess the impacts of seasonally altered streamflows on each species. The Grantee shall assess related impacts on the supplemental income of individuals engaged in the trapping and sales of these animals.

QUARTERLY ACTIVITIES

INVENTORY OF ANIMALS

No work was done in this area.

HABITAT TYPES

In cooperation with Task 2, vegetation types of islands and banks of the Yellowstone River were traced on overlays of 1:24,000 scale aerial photographs. All area and linear measurements will be obtained utilizing the digitized planimeter in the C. E. and E. M. Department, Montana State University, Bozeman.

EFFECT OF TRAPPING ON INCOME

No work was done in this area.

PRELIMINARY IMAPCT OF ALTERED STREAMFLOWS

Vegetated islands, island gravel bars, and lateral gravel bars of the Bighorn River were segregated into ten categories based on area in acres. Tables 26-28 show the absolute numbers of the three phenomena by river section in each area category prior to and after construction of Yellowtail Dam. The changes in makeup of these river formations are visually depicted as histograms (figures 16-18). The percentages of each category are shown in tables 29-31.

From the data presented it is obvious that there has been a marked change in the structure of the Bighorn River as a direct result of the impoundment behind Yellowtail Dam: the number of island gravel bars has been reduced from 619 to 301; and the number of lateral gravel bars has been reduced from 122 to 111. These reductions are accompanied by reductions in the average area of each resulting in greatly reduced total areas of the three river formations. Although there is some variation between sections, overall, the smaller islands and gravel bars now compose a higher percentage of the structures than they did prior to construction of the dam as a result of the river transporting sediment out of

TABLE 26. Absolute numbers of vegetated islands on the Bighorn River prior to and after Yellowtail Dam by area categories.

Section	Prior to Yellowtail Dam 1/ 1	2	3	4	5	Total	After Yellowtail Dam 2/ 1	2	3	4	5	Total
Area Category 3/												
1. 0-1.00	12	9	18	12	22	73	19	28	7	14	12	80
2. 1.01-2.00	10	11	16	11	12	60	5	15	8	9	5	42
3. 2.01-3.00	7	7	5	5	7	31	4	6	6	7	-	23
4. 3.01-4.00	3	5	6	2	4	20	2	7	6	7	4	26
5. 4.01-5.00	2	5	7	8	3	25	3	1	4	3	2	13
6. 5.01-10.00	7	12	17	13	6	55	3	8	3	5	2	21
7. 10.01-20.00	5	8	12	12	6	43	2	6	6	8	4	26
8. 20.01-50.00	4	19	17	14	4	58	3	9	7	4	7	30
9. 50.01-100.00	3	4	6	4	5	22	-	3	4	4	1	12
10. 100.01+	1	5	11	9	1	27	1	1	5	5	2	14
Total	54	85	115	90	70	414	42	84	56	66	39	287
Average size 4/	13.6	24.3	29.9	27.8	12.6	23.2	8.5	9.8	25.8	20.1	24.2	17.0
Total Area 5/	732	2063	3438	2500	884	9617	355	823	1447	1323	942	4891

1/ Taken from 1939 aerial photographs except section 5 taken from 1950 photographs.

2/ Taken from 1974 aerial photographs

3/ Area categories are in acres

4/ Average size is rounded to the nearest 0.1 acre.

5/ Total area is rounded to the nearest acre.

TABLE 27. Absolute numbers of island gravel bars on the Bighorn River prior to and after Yellowtail Dam by area categories.

Section	Prior to Yellowtail Dam 1/ 1	2	3	4	5	Total	After Yellowtail Dam 2/ 1	2	3	4	5	Total
Area Category 3/												
1. 0-0.50	8	16	9	-	65	98	20	20	12	19	15	86
2. 0.51-1.00	17	16	29	12	18	92	13	23	23	11	11	81
3. 1.01-2.00	9	19	27	27	18	100	8	16	22	13	12	71
4. 2.01-3.00	7	15	26	15	4	67	-	10	9	6	-	25
5. 3.01-4.00	9	13	18	15	3	58	1	4	6	4	3	18
6. 4.01-5.00	7	6	18	9	2	42	-	2	2	5	2	11
7. 5.01-6.00	3	5	8	2	1	19	-	-	3	2	2	7
8. 6.01-10.00	9	12	27	13	1	62	-	-	-	-	1	1
9. 10.01-20.00	8	21	17	15	1	62	-	-	-	1	-	1
10. 20.01+	2	8	4	5	-	19	-	-	-	-	-	-
Total	79	131	183	113	113	619	42	75	77	61	46	301
Average Size 4/	4.4	6.2	4.8	6.1	0.9	4.6	0.7	1.3	1.5	1.7	1.5	1.4
Total Area 5/	350	810	875	690	106	2830	30	95	119	103	67	413

1/ Taken from 1939 aerial photographs except section 5 taken from 1950 photographs

2/ Taken from 1974 aerial photographs

3/ Area categories in acres

4/ Average size rounded to nearest 0.1 acre

5/ Total area rounded to nearest acre

TABLE 28. Absolute numbers of lateral gravel bars on the Bighorn River prior to and after Yellowtail Dam by area categories.

Section	Prior to Yellowtail Dam 1/						After Yellowtail Dam 2/					
	1	2	3	4	5	Total	1	2	3	4	5	Total
Area Category 3/												
1. 0-0.50	2	1	1	-	9	13	6	3	2	2	2	15
2. 0.51-1.00	2	2	1	-	3	8	5	5	9	7	4	30
3. 1.01-2.00	4	13	-	10	3	30	7	5	3	5	4	24
4. 2.01-3.00	6	5	4	2	1	18	-	3	5	4	2	14
5. 3.01-4.00	-	9	1	1	1	12	1	4	4	1	2	12
6. 4.01-5.00	6	-	3	-	-	9	1	-	1	3	1	6
7. 5.01-6.00	-	2	-	2	-	4	-	-	1	-	-	1
8. 6.01-10.00	2	2	3	1	1	9	-	1	1	-	3	5
9. 10.01-20.00	3	4	2	3	1	13	-	2	2	-	-	4
10. 20.01+	1	2	1	2	-	6	-	-	-	-	-	-
Total	26	40	16	21	19	122	20	23	28	22	18	111
Average Size 4/	5.0	4.8	6.2	6.9	1.7	4.9	1.2	2.7	2.9	1.8	2.7	2.3
Total Area 5/	129	191	99	144	32	595	25	61	81	40	48	254

1/ Taken from 1939 aerial photographs except section 5 taken from 1950 photographs

2/ Taken from 1974 aerial photographs

3/ Area categories in acres

4/ Average size rounded to nearest 0.1 acre

5/ Total area rounded to nearest acre

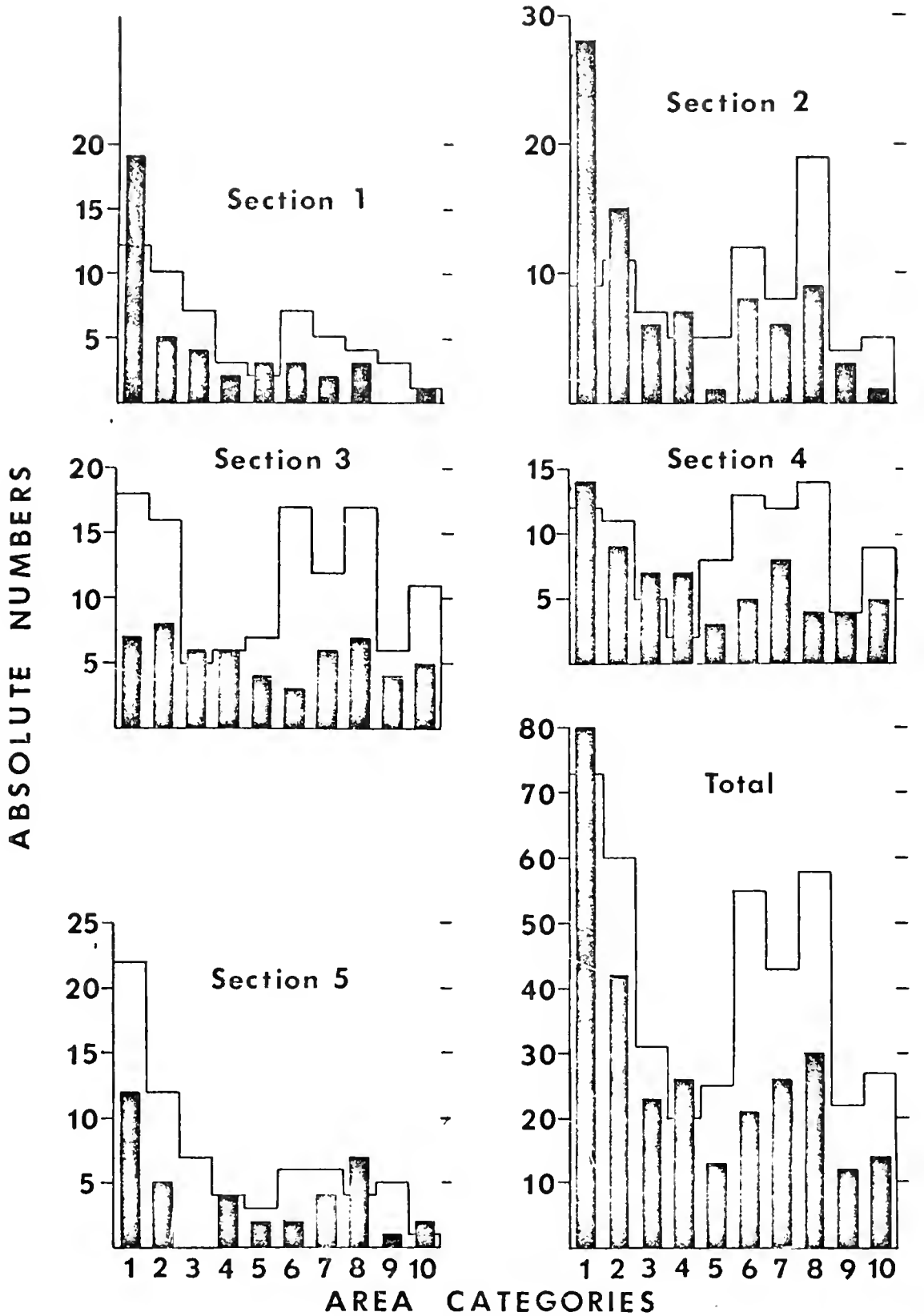


Figure 16. Absolute numbers of vegetated islands on the Bighorn River by area categories (see table 29) prior to Yellowtail Dam - Line Graph - and after Yellowtail Dam - Bar Graph.

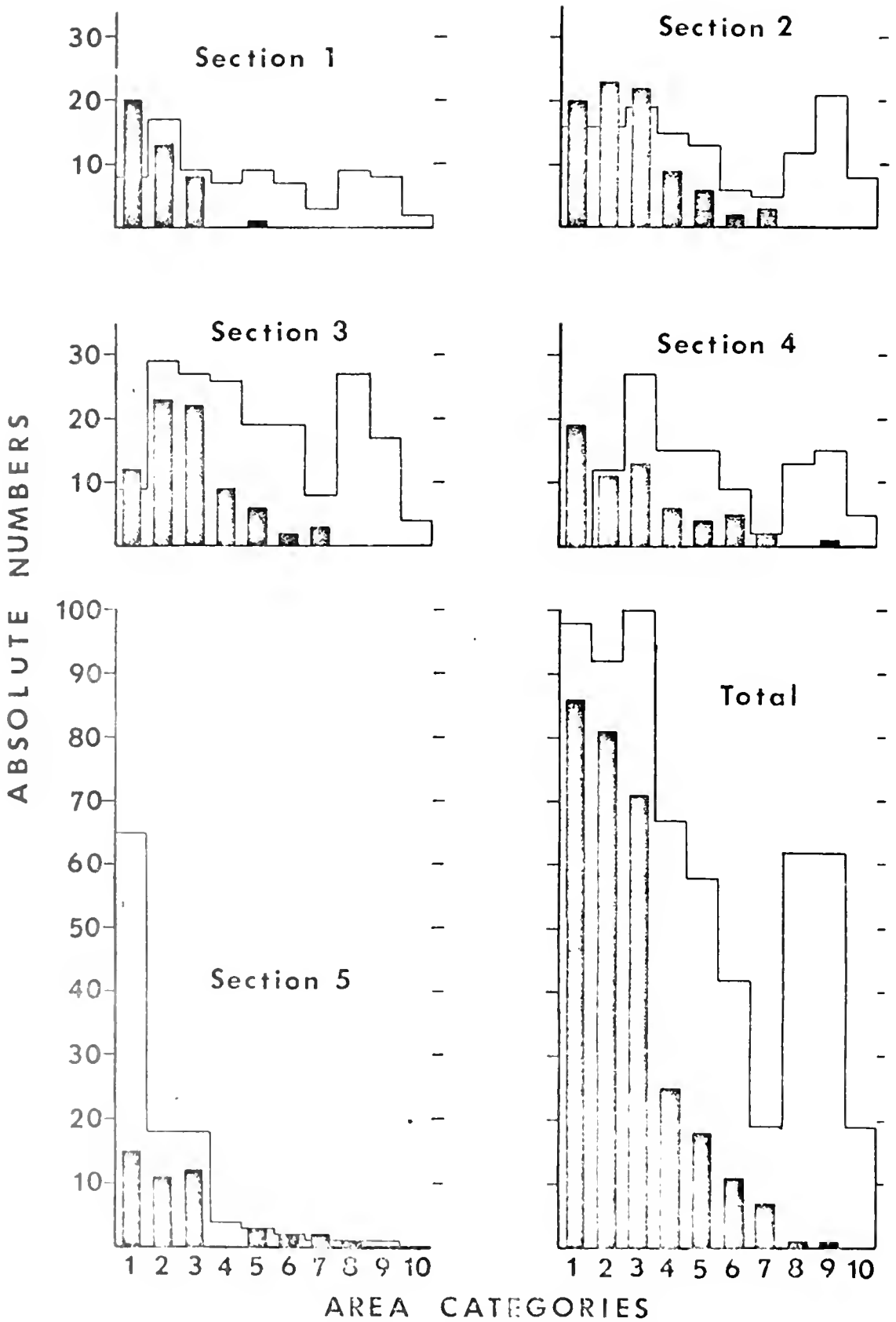


Figure 17. Absolute numbers of island gravel bars on the Bighorn by area categories (see table 30) prior to Yellowtail Dam - Line Graph - and after Yellowtail Dam - Bar Graph.

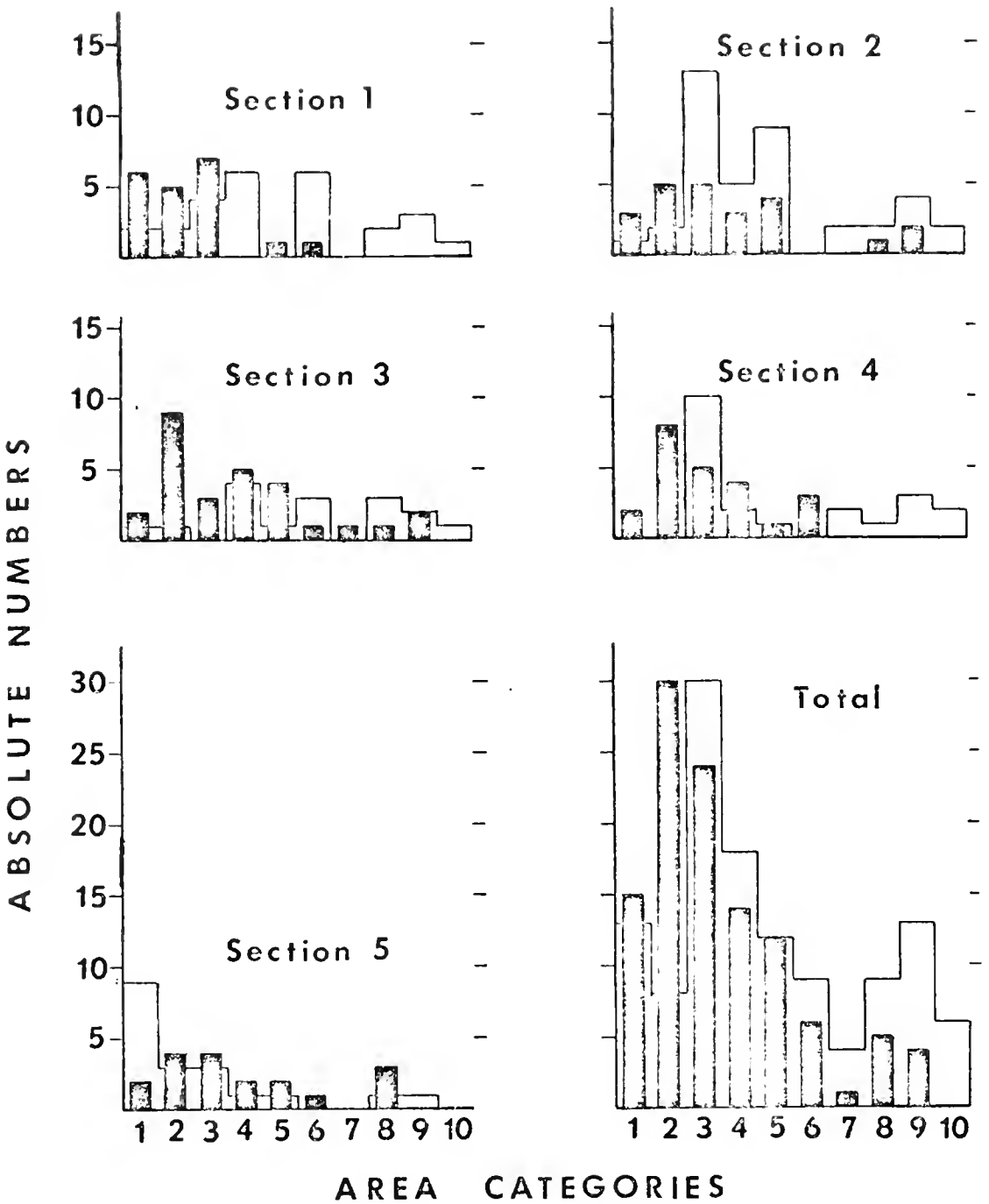


Figure 18. Absolute numbers of lateral gravel bars on the Bighorn River by area categories (see table 31) prior to Yellowtail Dam - Line Graph - and after Yellowtail Dam - Bar Graph.

TABLE 29. Percentages of vegetated islands on the Bighorn River prior to and after Yellowtail Dam by area categories.

Section	Prior to Yellowtail Dam 1/ 1	2	3	4	5	Total	After Yellowtail Dam 2/ 1	2	3	4	5	Total
Area Category 3/												
1. 0-1.00	22 4/	11	16	13	31	18	45	33	13	21	31	28
2. 1.01-2.00	19	13	14	12	17	15	12	18	14	14	13	15
3. 2.01-3.00	13	8	4	6	10	7	10	7	11	11	-	8
4. 3.01-4.00	6	6	5	2	6	5	5	8	11	11	10	9
5. 4.01-5.00	4	6	6	9	4	6	7	1	7	5	5	5
6. 5.01-10.00	13	14	15	14	9	13	7	10	5	7	5	7
7. 10.01-20.00	9	9	10	13	9	10	5	7	11	12	10	9
8. 20.01-50.00	7	22	15	16	6	14	7	11	13	6	18	10
9. 50.01-100.00	6	5	5	5	7	5	-	4	7	6	3	4
10. 100.01+	2	6	10	10	1	7	2	1	9	7	5	5

1/ Taken from 1939 aerial photographs except section 5 taken from 1950 photographs

2/ Taken from 1974 aerial photographs

3/ Area categories in acres

4/ Percentages rounded to nearest whole number

TABLE 30. Percentages of island gravel bars on the Bighorn River prior to and after Yellowtail Dam by area categories.

Section	Prior to Yellowtail Dam 1/ 1	2	3	4	5	Total	After Yellowtail Dam 2/ 1	2	3	4	5	Total
Area Category 3/												
1. 0-0.50	10 4/	12	5	-	58	16	48	27	16	31	33	29
2. 0.51-1.00	22	12	16	11	16	15	31	31	30	18	24	2
3. 1.01-2.00	11	15	15	24	16	16	19	21	29	21	26	24
4. 2.01-3.00	9	11	14	13	4	11	-	13	12	10	-	8
5. 3.01-4.00	11	10	10	13	3	9	2	5	8	7	7	6
6. 4.01-5.00	9	5	10	8	2	7	-	3	3	8	4	4
7. 5.01-6.00	4	4	4	2	1	3	-	-	4	3	4	2
8. 6.01-10.00	11	9	15	11	1	10	-	-	-	-	2	tr 5/
9. 10.01-20.00	10	16	9	13	1	10	-	-	-	2	-	tr
10. 20.01+	3	6	2	4	-	3	-	-	-	-	-	-

1/ Taken from 1939 aerial photographs except section 5 taken from 1950 photographs

2/ Taken from 1974 aerial photographs

3/ Area categories in acres

4/ Percentages rounded to nearest whole number

5/ tr = trace; a value less than 0.50 percent.

TABLE 31. Percentages of lateral gravel bars on the Bighorn River prior to and after Yellowtail Dam by area categories.

Section	Prior to Yellowtail Dam 1/						After Yellowtail Dam 2/					
	1	2	3	4	5	Total	1	2	3	4	5	Total
Area Category 3/												
1. 0-0.50	8 4/	3	6	-	47	11	30	13	7	9	11	14
2. 0.51-1.00	8	5	6	-	16	7	25	22	32	32	22	27
3. 1.01-2.00	15	33	-	48	16	25	35	22	11	23	22	22
4. 2.01-3.00	23	13	25	10	5	15	-	13	18	18	11	13
5. 3.01-4.00	-	23	6	5	5	10	5	17	14	5	11	11
6. 4.01-5.00	23	-	19	-	-	7	5	-	4	14	6	5
7. 5.01-6.00	-	5	-	10	-	3	-	-	4	-	-	1
8. 6.01-10.00	8	5	19	5	5	7	-	4	4	-	17	5
9. 10.01-20.00	12	10	13	14	5	11	-	9	7	-	-	4
10. 20.01+	4	5	6	10	-	5	-	-	-	-	-	-

1/ Taken from 1939 aerial photographs except section 5 taken from 1950 photographs

2/ Taken from 1974 aerial photographs

3/ Area categories in acres

4/ Percentages rounded to the nearest whole number

the area. Since most sediment has settled out in the impoundment area, the river tends to cut down below the level of meanders, confining itself to one channel. Thus islands are eliminated and gravel bars are carried away.

The problem is complicated by the controlled flow situation, i.e. elimination of peak spring runoff. Vegetation is now able to grow down to the water's edge in many places, further reducing the number and size of gravel bars. However, the most important effect is the elimination of the major force involved in the formation of new islands. Without the formation of new islands, eventually all vegetation will reach the climax stage, in this case probably some combination of mature cottonwood and grasses. The combined effects of island and gravel bar elimination and succession of vegetation to climax portends a large decrease in habitat available for furbearers, as well as other mammals and waterfowl.

Tongue River

High Scenario. With virtually no flow at the 90 percentile level and with flow only during July at the 50 percentile level, beaver and other furbearer populations would be subjected to extreme stress and probably to elimination. Without water for protection and escape, beaver would be vulnerable to attack by predators. They would attempt to build dams for impounding water, resulting in extensive damage to cottonwood and willow stands on the flood plain. Elimination of this vegetation would have several side effects. First, it would decrease the available food supply for the beaver. Second, it would weaken bank resistance to erosion by high water during run-off periods. Third, it would reduce habitat for other wildlife species including deer, game birds, song birds, and raptors which use cottonwoods and willows for nesting and protective cover.

With virtually no flow during the winter period, even if beaver were able to construct dams with shallow backwaters, caches would probably become frozen over, and beaver would be forced to feed on willows still standing. In this case they would be very vulnerable to predation. Perhaps more important, they would have to venture into a cold environment to obtain food. They would undoubtedly expend more energy obtaining the food than they derived from it, resulting in drastic deterioration of health and eventual death from exposure.

The greatly reduced spring flows would eliminate what little new island and gravel bar formation is now taking place under the controlled flow situation. As discussed in the first part of this section, reduced spring flows eventually result in loss of beaver habitat, as well as habitat for other wildlife species.

Intermediate Scenario. Beaver and other furbearers would most likely suffer reduced population levels under this scenario. At the 90 percentile flow level, there would be no flow during the months of July through October and only 34 acre-feet during June. At the 50 percentile level, there would be no flow in July and August. The June flow would be about 60 percent below the low scenario June flow. These flows, or lack of flows, would trigger a dam-building effort by beaver with the same detrimental effects on the habitat discussed in the high scenario section. Beaver would also be vulnerable to predation during this time.

Late fall, winter, and early spring flows, if they are maintained without large diurnal fluctuations, would seem to be sufficient to allow cache construction in most locations and access to them under the ice.

The long-term effects of the elimination of peak spring flows would be the same as discussed earlier, that is, reduction in available habitat.

Low Scenario. There probably would be very little stress placed on beaver and other furbearers above that which is already there under the present management situation. The river would have flows at all times during the year under both 90 and 50 percentile flow levels. The low flows occurring in August and September could result in dam building efforts in some locations, but certainly not as extensive as in the other two scenarios.

Spring run-off peaks would not be as high as natural flows, but this probably wouldn't have a large effect as most of the damage to the Tongue River islands and gravel bars has already been done.

Bighorn River

High Scenario. Flows during all months at the 90 percentile level would be substantially reduced, with no flow at all in July and only 0.14 acre-feet in August. Summer flows would also be low at the 50 percentile level. These low flows would result in dam-building efforts by beaver, especially in the braided and split channel sections of the river. A return to near-normal flows in the fall and winter months would probably result in the destruction of most of the make-shift beaver dams and a complete loss of the material in the dams as a food source. The effects of dam building discussed in the Tongue River section also apply on the Bighorn.

The further reduction of spring peak run-off would accelerate the decline in numbers of vegetated islands and gravel bars previously documented in this study. The result would be a reduction in beaver habitat and beaver population levels.

Intermediate Scenario. There are no dry months at either the 90 or 50 percentile flow levels in this scenario. The lowest flows, again during July and August, would probably, at the 90 percentile level, result in extensive dam building in braided sections. At the 50 percentile level, dam building activities would probably not be much more than normal. Flows during the remainder of the year are not much different from historical flows; hence no impacts on furbearer populations could be directly attributed to withdrawals in most years. Probably only during dry years would the additional withdrawals exert additional stress on the furbearer populations. Since the construction of Yellowtail Dam is past history, most of the damage has already been done and the eventual fate of the beaver population levels is largely ascertained.

Low Scenario. Flows would not be much different from the intermediate level in this scenario; consequently, the effects on the furbearer populations would be nearly identical to those discussed in the preceding section. Since the total diversion and depletion is less than in the intermediate scenario, the

exceptionally dry years would probably be the only years in which furbearer populations would be better off under the low scenario than under the intermediate.

Mid-Yellowstone River

High Scenario. The free-flowing status of the Yellowstone River is its most valuable quality in relation to furbearer populations. The continual formation of new islands and gravel bars assures an adequate food supply in the form of willows and young cottonwood trees. The only months in which flows are much below historic levels are July, August, and September. Some dam building possibly would be experienced at the 90 percentile flow levels of this scenario, but only in the braided sections of the river. This would have the same effect as described in earlier sections of this report but would not be as critical as on either the Tongue or Bighorn rivers where available habitat has already been greatly reduced. As long as beaver are able to construct caches in locations which are accessible under the winter ice, they will survive. If normally stable winter and early spring flows are maintained, the furbearers will probably not suffer greatly.

Intermediate and Low Scenarios. The same comments made in the above section apply to these two scenarios. Deviations from historic flows appear to be small in all months except possibly July and August. Most likely, the water diversions and depletions projected, since they require no impoundments on the mainstem of the Yellowstone, would have very little effect on furbearer populations.

ANTICIPATED ACTIVITIES FOR NEXT QUARTER

Final analysis of all data gathered will be commenced. Final graphs will be drawn, and vegetation analysis will be completed.

Task 3 is about 80% completed.

TASK 4. ASSESSMENT OF THE IMPACT OF ALTERED STREAM FLOWS ON AGRICULTURE WHICH IS DEPENDENT UPON IRRIGATION. The Grantee shall estimate the future demand for agricultural projects provided by irrigated farming. The Grantee shall project what further irrigation development could occur in the study area on the basis of the existing resource base. The Grantee shall ascertain and, insofar as possible, quantify potential physical and economic constraints that may result from the use of water for coal development.

IRRIGABLE LANDS ANALYSIS

INTRODUCTION

Irrigated agriculture in the Yellowstone Basin has increased from 385,000 acres in 1964 to 461,000 acres in 1973 (USDA Statistical Reporting Service 1964-1974). Most of this increase occured in 1972 and 1973 (Montana DNRC 1975c) indicating a recent surge of interest in irrigation. Projection of future irrigation development should not be based solely on recent trends, however, but should also consider the availability of suitable land and the cost of applying water to the land.

METHODS

One method of investigating irrigation potential is to compare the cost of delivering water to the land with farmers' ability to pay the costs. The economic feasibility of irrigating the land can then be determined, and projections of future irrigation made. This comparison can be done if the following information is available:

1. The payment capacity of the land.
2. The location of the land with respect to the water supply.
3. The cost of the irrigation system.

Payment Capacity

The payment capacity of the land is directly related to the types of crops grown. Farm budgets, reflecting the cropping patterns used in the basin, have been used to compute the payment capacity. The budgets were developed using a computerized linear programming model and were designed to compute the per-acre payment of the land (Montana DNRC 1976). All crops used in the budgets reflect both current and future farming practices. Sugar beets, for example, currently grown extensively in the basin, are representative of all high-value cash crops which may be grown in the future. Similarly, barley represents all grain crops, and alfalfa, all hay crops. Various mixes of these crops, plus a livestock production budget, have been used to reflect local growing conditions and farmer preferences throughout the basin.

Location of Irrigable Land

The location of irrigable land with respect to water supply is a critical factor in determining total irrigation costs. For this study, water supplies were limited to the Yellowstone, Powder, Tongue, Bighorn, and Clarks Fork Yellowstone rivers. All irrigable lands adjacent to these rivers were identified on a land classification map (Montana DNRC 1975a). Topographic maps were then projected onto the land classification maps, and all irrigable land was tabulated according to distance from the river (½ mile increments) and elevation above the river (50 ft. increments). The acreages were then tabulated by county and subbasin.

Irrigation Costs

The irrigation costs were separated into costs associated with delivering the water to the farm and costs of applying the water to the land.

Water delivery costs were determined for several farm sizes at a range of elevations and distances from the water supply and were calculated for concrete as well as steel pipe. Annual costs were obtained by amortizing the initial cost (pumps, pipe, houses, electrical equipment, and installation costs) over a 10-year period at 10 percent interest. Annual operation costs (labor, maintenance, repairs, and electricity costs) were then added to the amortized initial costs to arrive at total annual costs.

The annual costs of all on-farm irrigation equipment, for both surface irrigation systems and sprinkler systems, were developed in a similar manner. A contour furrow system was used to represent surface irrigation systems, and a center pivot sprinkler represents the sprinkler systems. The sprinkler systems were further analyzed by calculating the per-acre costs for one sprinkler shared between two fields and one sprinkler for each field.

RESULTS

Figure 19 shows the payment capacity for several cropping patterns prevalent in the Yellowstone Basin. These payment capacities are used to determine the financial feasibility of the operation, i.e., the ability of the land to generate enough profit to meet the loan payments and all operating costs of the irrigation system. However, farming operation may be financially feasible, but still not produce more profit than a dryland operation, thus not warranting development.

Cropping Pattern Analysis

Grain. Recent increases in wheat prices have stimulated an interest in irrigated grain crops. These prices will easily warrant irrigation development (Luft 1976). However, long-term prices developed by the Water Resources Council (1974) indicate that irrigated grain farming may be only marginally feasible. Sensitivity analysis of the farm budgets indicates that the payment capacity is extremely sensitive to the selling price of grain. Therefore, projection of future irrigation on the basis of grain crops at current prices must be viewed with caution.

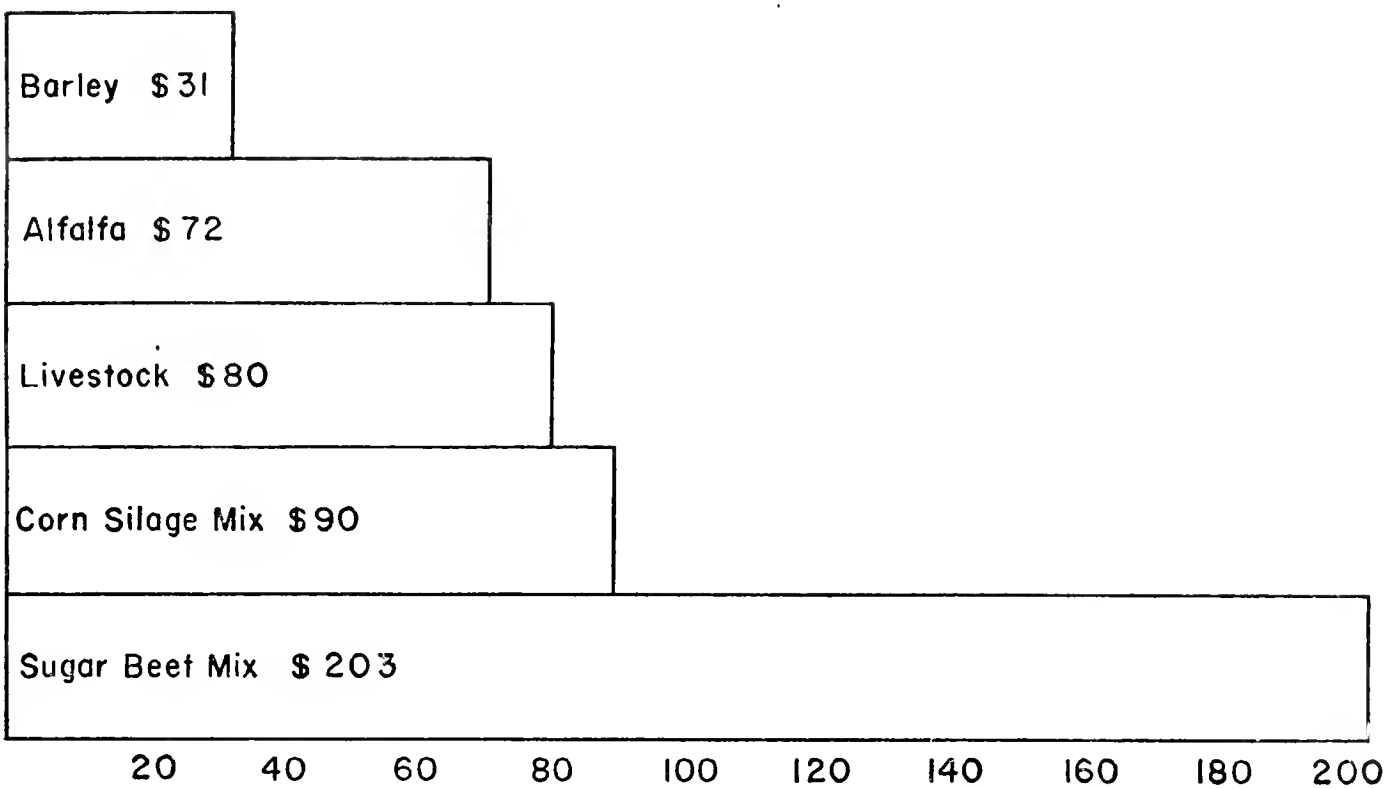


FIGURE 19. Per-Acre Payment Capacity.

Alfalfa. Alfalfa is produced throughout the basin. In addition to hay for sale, this crop is often grown for winter livestock feed, producing a stabilizing effect on the ranching operation. While this stabilizing effect cannot be measured quantitatively, it does have a great influence on the decision to irrigate and therefore should be considered when projecting future irrigation.

Although alfalfa production for winter feed may not be sensitive to small price fluctuations, small changes in yield projections do affect the feasibility of irrigating alfalfa. When high levels of management are used on alfalfa, correspondingly high yields must be obtained to insure profitability. A drop in yield of 1 ton per acre may cost the farmer over $30.00 per acre in lost revenue and cause the operation to become unprofitable if water delivery costs are high. However, if the farmer is currently producing dryland alfalfa, an increased yield of only 1 ton per acre can produce enough profit to install a surface irrigation system if the water supply is adjacent to the farm.

These results indicate that irrigated alfalfa production can be feasibly developed on lands within ½ mile of the river and less than 50 feet above the river. Projection of development above this limit will require the consideration of future prices, yield fluctuations, and the stability factor for livestock production.

Livestock Production. The payment capacity for livestock production on irrigated agricultural land was analyzed by assuming a feeder operation. Calves would be bought from the rancher's own herd at fair market value, then fed alfalfa, corn silage, and barley, and sold as yearling steers in the spring. The net profit can be directly related to the value of irrigated crops. This type of operation provides some degree of stability, since the rancher has the option of feeding the calves or selling both the feed and the calves in the fall. This option reduces the effect of price fluctuations, while the effect of crop yield fluctuations can be reduced by varying the feed ration (within the limits of nutritional requirements). However, if the feed is sold in the fall, the payment capacity of the irrigated land is reduced from $80.00 per acre to $36.00 per acre, a value reduction which will greatly affect the projection of future irrigation development.

Corn Silage. Corn silage is produced throughout much of the basin except for portions of the upper Yellowstone and the upper reaches of the tributaries which may have too-short growing seasons. For these calculations, it was assumed that corn silage was grown in rotation with barley and alfalfa to insure maximum soil fertility and crop production. This diversity of crops reduces the effect of price and yield fluctuations. However, since both corn silage and alfalfa are sensitive to yield fluctuations, projection of future development should consider these problems.

Sugar Beets. Sugar beet production has the highest payment capacity of all crops grown in the basin. Recent developments in the sugar beet industry make it difficult to project future beet production, however. The availability of beet processing facilities restricts production to current levels. Some of the factors involved in projecting beet production include:

1. Economics of new plant construction.

2. Economics of expanding present facilities.

3. Recent contract negotiation problems.

4. Economics of meeting water quality requirements.

Each of these problems must be considered when making future sugar beet irrigation projections.

Preliminary Results

The payment capacities developed from the farm budgets are used to pay all irrigation costs. These costs have been separated into two categories: 1) on-farm irrigation costs, and 2) costs of delivering water to the farm gate.

On-farm costs for a surface irrigation system were obtained from the U.S. Bureau of Reclamation (1975) and include land preparation, ditch and dam construction, siphon tubes, labor, and other equipment required for operation and maintenance of the system. The total annual cost for this type of system is $31.00 per acre. A center pivot electric sprinkler system costs $60.00 per acre, including all equipment, labor, maintenance, and electricity costs. These costs were obtained from the Cooperative Extension Service (1969) and indexed to October 1974 prices.

Table 32 shows the cost of delivering water to a 320-acre farm situated at a range of distances and elevations from the river. All costs were developed from U.S. Bureau of Reclamation (1975) data and include installation, operation, and maintenance. Concrete pipe was assumed for lower lift requirements and steel pipe for higher elevations.

Using these data, barley and alfalfa production are infeasible when both water delivery costs and on-farm irrigation costs are considered. Production of livestock, corn silage, or sugar beets is feasible. However, the Bureau of Reclamation data are based on large projects with high volumes of water involved. Extrapolation of these data to the smaller projects appears to create exaggerated cost estimates for the smaller lifts, distances, and project sizes. The magnitude of this error is expected to decrease as the lifts, distances, and project sizes increase. Correction and refinement of these cost estimates will continue.

Tables 33 through 41 display the available land resource by subbasin, organized within each table by pumping lift and distance from water supply. A preliminary estimate of irrigation potential can be made by applying the economic constraints in table 32 to the land resource acreages in tables 33 through 41.

TABLE 32. Water Delivery Costs (annual, per-acre costs for 320 acre farm).

Pipe Length (mi.)	Elevation (FT) 50	100	150	200	250	300	350	400	450
.5	50.80	62.30	72.80	96.40	106.60	124.90	135.00	153.20	163.30
1.0	72.90	85.00	121.90	132.10	153.80	168.60	190.30	204.90	226.70
1.5	94.90	107.70	157.60	185.00	195.30	229.70	239.80	274.10	284.20
2.0	117.00	130.40	194.60	226.40	236.70	279.20	289.30	331.70	341.80
2.5	139.10	153.10	230.70	267.90	278.20	328.70	338.80	389.30	*
3.0	161.10	175.80	266.80	309.40	319.60	378.20	388.30	446.80	*
3.5	183.20	198.50	302.90	350.80	360.10	427.70	437.90	504.40	*
4.0	205.20	221.20	339.00	392.30	402.60	477.20	487.40	561.90	*
4.5	233.30	364.70	423.50	433.80	516.50	526.70	609.40	*	*
5.0	256.00	400.80	464.90	475.20	566.00	576.20	666.90	*	*

* Steel pipe will break at these pressures.

TABLE 33. Irrigable acreage by lift and distance requirements: Upper Yellowstone.

Lift (Ft)	Distance (mi)	Acres
50	.5	40,236
100	.5	1,406
100	1.0	1,607
100	1.5	670
100	2.0	2,391
150	1.5	1,671
150	2.0	1,006
200	.5	766
200	1.5	3,252
250	2.5	3,715
300	.5	442
300	1.0	3,962
300	1.5	3,432
300	2.0	1,533
300	3.0	891
350	3.0	710
400	1.0	1,601
400	1.5	2,157
400	2.0	2,649
400	3.5	657
450	1.5	1,087
450	2.0	3,613
500	2.5	569

TABLE 34. Irrigable acreage by lift and distance requirements: Billings Area.

Lift (Ft)	Distance (mi)	Acres
50	.5	3,308
50	1.0	347
50	1.5	110
100	.5	3,324
100	1.0	71
100	2.0	165
100	3.0	118
150	.5	329
150	1.0	8,084
150	1.5	3,549
150	4.5	673
200	.5	2,147
200	1.0	1,305
200	1.5	585
250	1.5	442
250	2.0	998
300	.5	222
300	1.0	1,254
300	1.5	878
350	2.0	278
400	1.0	447
400	2.0	2,325
400	2.5	446
450	2.5	662

TABLE 35. Irrigable acreage by lift and distance requirements: Bighorn River (below Reservation).

Lift (Ft)	Distance (mi)	Acres
50	.5	850
50	1.0	330
100	1.0	383
100	2.5	1,387
100	3.5	593
150	.5	697
150	1.0	949
150	2.0	1,431
150	2.5	581
150	3.0	3,734
150	3.5	1,178
150	4.0	1,056
150	4.5	655
200	1.0	1,054
200	2.0	783
200	3.0	1,159
200	4.5	531
300	2.0	384

TABLE 36. Irrigable acreage by lift and distance requirements: Mid-Yellowstone.

Lift (Ft)	Distance (mi)	Acres
50	.5	16,000
50	1.0	3,180
50	2.0	820
100	.5	1,691
100	1.0	4,358
100	1.5	4,004
100	2.0	257
100	2.5	428
150	1.0	4,616
150	2.0	2,693
150	3.0	1,979
200	1.0	2,802
200	1.5	2,270
200	2.0	6,681
200	2.5	3,534
200	4.5	704
250	1.0	297
250	1.5	4,522
250	2.0	3,353
250	3.5	710
300	1.5	309
300	2.0	1,149
300	2.5	4,851
300	3.0	2,459
300	3.5	3,514
350	1.5	2,071
350	3.0	1,538

TABLE 37. Irrigable acreage by lift and distance requirements: Kinsey Area .

Lift (Ft)	Distance (mi)	Acres
50	.5	3,248
50	1.5	308
100	1.5	2,035
100	2.0	464
150	1.0	539
200	.5	1,180
300	1.5	731
300	2.0	546
350	2.0	1,405
400	3.5	1,867

TABLE 38. Irrigable acreage by lift and distance requirements: Tongue River .

Lift (Ft)	Distance (mi)	Acres
50	.5	21,947
200	1.5	983
250	1.5	1,004
300	2.5	529

TABLE 39. Irrigable acreage by lift and distance requirements: Powder River .

Lift (Ft)	Distance (mi)	Acres
50	.5	74,224
50	1.0	981
250	1.5	993
300	1.5	1,288
300	2.0	2,612
350	2.5	6,872
350	3.0	904
400	3.0	27,040

TABLE 40: Irrigable acreage by lift and distance requirements: Lower Yellowstone

Lift (Ft)	Distance (mi)	Acres
50	.5	23,677
50	1.0	1,813
100	.5	1,804
100	1.0	4,992
100	1.5	2,599
100	2.0	805
100	3.0	963
150	.5	1,775
150	1.5	792
150	2.0	4,807
200	1.5	386
200	2.0	2,120
200	2.5	350
200	3.0	355
250	2.0	1,603
250	3.5	1,376
250	4.0	370
300	2.0	564
300	3.5	2,621
350	2.0	537
350	3.0	1,341
350	3.5	458
400	1.0	4,887
400	1.5	12,389
400	2.0	290

TABLE 40. (continued).

Lift (ft)	Distance (mi)	Acres
400	2.5	5,101
400	3.0	6,563
450	3.5	9,235

TABLE 41: Irrigable acreage by lift and distance requirements: Basin Summary.

Lift (Ft)	Distance (mi)	Acres
50	.5	183,490
50	1.0	6,651
50	1.5	418
50	2.0	820
100	.5	8,225
100	1.0	11,411
100	1.5	9,308
100	2.0	4,082
100	2.5	1,815
100	3.0	1,081
100	3.5	593
150	.5	2,801
150	1.0	14,188
150	1.5	6,012
150	2.0	9,997
150	2.5	581
150	3.0	5,713
150	3.5	1,178
150	4.0	1,056
150	4.5	1,328
200	.5	4,093
200	1.0	5,161
200	1.5	7,476
200	2.0	9,584
200	2.5	3,884
200	3.0	1,514

TABLE 41. (continued) .

Lift (Ft)	Distance (mi)	Acres
200	4.5	1,235
250	1.0	297
250	1.5	6,961
250	2.0	5,954
250	2.5	3,715
250	3.5	2,086
250	4.0	370
300	.5	664
300	1.0	5,216
300	1.5	6,638
300	2.0	6,788
300	2.5	5,380
300	3.0	3,350
300	3.5	3,972
350	1.5	2,077
350	2.0	2,220
350	3.0	4,493
350	3.5	458
400	1.0	6,935
400	1.5	14,546
400	2.0	5,264
400	2.5	5,547
400	3.0	33,603
400	3.5	2,524
450	1.5	1,087
450	2.0	3,613
450	2.5	1,231
450	3.5	9,235

Livestock, corn silage, and sugar beet production all generate enough profit to pay on-farm irrigation costs plus some water delivery costs. If surface irrigation methods are assumed, livestock and corn silage production can be irrigated up to one half mile and 50 ft. above the river. Excluding areas in Park and Sweetgrass counties where corn silage is not grown, an additional 151,622 acres can be irrigated. Sugar beet production will permit an additional 228,576 irrigated acres. Center pivot irrigation will permit irrigation of 215,656 acres with sugar beets but is infeasible with livestock or corn silage.

ACTIVITIES PLANNED FOR NEXT QUARTER

Water delivery costs will be corrected, dryland farm budgets will be developed to determine economic feasibility, and projections of future irrigation will be made.

CROSS-SECTION SURVEYS

Following is a list of diversion sites which have been surveyed and analyzed with respect to reduced streamflows.

Sidney #1. Yellowstone River.

This site has been cross sectioned and the water surface profile and increased pumping costs have been determined for various flows in the river. This site has been completed.

Sidney #3. Yellowstone River.

Same as #1--completed.

Intake #4. Yellowstone River.

Cross sections have been completed and water surface profiles have been determined for various flows. Some survey work needs to be done on the canal below the headgate before the analysis of this site can be completed.

Kinsey #7. Yellowstone River.

Cross sections and water surface profiles have been completed. Pump curves and sizes are needed for this site.

T & Y #8. Tongue River.

All field data has been collected for this site. The analysis of streamflow vs cost to divert has not been completed.

Muggli #9. Tongue River.

All information has been gathered for this site. The analysis has not been completed.

Forsyth #11. Yellowstone River.

All field data except for the elevation of the crest of the diversion dam has been acquired.

Victory Ditch #17. Bighorn River.

Cross section surveys have been completed for the river, but some surveying needs to be done on the headgate and the canal below the headgate.

Glendive #35. Yellowstone River.

All field surveying has been completed. The water surface profiles have not been completed nor have pump curves been acquired.

Hysham #36. Yellowstone River.

Two cross sections need to be taken on the river, and some surveying must be done on the canal below the headgate.

Three city water supply systems--Miles City, Hardin, and Billings--will be evaluated to determine the relationship between river flow and pumping costs. This can be done by relating the cost to pump a unit of water to the flow in the river. All three sites have a stream gaging station nearby.

When all of these sites are completed, the following categories of sites will have been analyzed:

4 federal irrigation projects
4 state irrigation projects
2 private irrigation projects
4 municipal projects

NEXT QUARTER'S ACTIVITIES

Field surveys, pump curves, and other missing information will be gathered. The analysis will be completed during the following quarter.

Task 4 is about 85% completed.

TASK 5. ASSESSMENT OF THE IMPACT OF ALTERED STREAM FLOWS ON MUNICIPAL AND NON-ENERGY INDUSTRIAL WATER SUPPLIES. The Grantee shall identify existing uses and sources of supply. The Grantee shall project future water needs for existing municipalities and for selected developing communities. The Grantee shall then assess the effects of water storage and diversion upon each community.

PRELIMINARY SCENARIOS

The preliminary impacts presented throughout this report are based on a set of preliminary agriculture and energy development scenarios. At this point, the agriculture scenarios are somewhat arbitrary and do not reflect many of the considerations currently being developed in Task 4. The energy scenarios are modifications of the scenarios presented in the previous quarterly report (Montana DNRC 1976). These energy scenarios are currently being further revised and will be presented with supporting data and logic in a subsequent report.

Tables 42 through 52 show the preliminary scenarios, on a monthly water diversion and depletion basis, for the four subbasins simulated by the State Water Planning Model (see Task 9). Note that there is no low scenario for the Powder River subbasin at this time.

Task 5 is about 80% completed.

TABLE 42. Water requirements. Year 2000. Preliminary low scenario. Tongue River subbasin (42B&C).

Water Requirements (AF)

	Energy		Irrigation		Municipal		Total	
	Div.	Dep.	Div.	Dep.	Div.	Dep.	Div.	Dep.
Jan.	250	250	-	-	Neg.	Neg.	250	250
Feb.	250	250	-	-	Neg.	Neg.	250	250
Mar.	250	250	-	-	Neg.	Neg.	250	250
April	250	250	170	120	Neg.	Neg.	420	370
May	250	250	2,260	1,510	Neg.	Neg.	2,510	1,760
June	250	250	2,960	1,970	Neg.	Neg.	3,210	2,220
July	250	250	5,570	3,710	Neg.	Neg.	5,820	3,960
Aug.	250	250	4,350	2,900	Neg.	Neg.	4,600	3,150
Sept.	250	250	1,920	1,270	Neg.	Neg.	2,170	1,520
Oct.	250	250	170	120	Neg.	Neg.	420	370
Nov.	250	250	-	-	Neg.	Neg.	250	250
Dec.	250	250	-	-	Neg.	Neg.	250	250
Annual	3,000	3,000	17,400	11,600	Neg.	Neg.	20,400	14,600

Strip mine 59 mmt/yr

Irrigate 5,800 new acres

TABLE 43. Water requirements. Year 2000. Preliminary intermediate scenario. Tongue River subbasin (42B&C).

Water Requirements (AF)

	Energy		Irrigation		Municipal		Total	
	Div.	Dep.	Div.	Dep.	Div.	Dep.	Div.	Dep.
Jan.	3,640	3,640	-	-	Neg.	Neg.	3,640	3,640
Feb.	3,640	3,640	-	-	Neg.	Neg.	3,640	3,640
Mar.	3,640	3,640	-	-	Neg.	Neg.	3,640	3,640
April	3,640	3,640	580	390	Neg.	Neg.	4,220	4,030
May	3,640	3,640	7,560	5,040	Neg.	Neg.	11,200	8,680
June	3,640	3,640	9,890	6,590	Neg.	Neg.	13,530	10,230
July	3,640	3,640	18,620	12,410	Neg.	Neg.	22,260	16,050
Aug.	3,640	3,640	14,540	9,700	Neg.	Neg.	18,180	13,340
Sept.	3,640	3,640	6,400	4,270	Neg.	Neg.	10,040	7,910
Oct.	3,640	3,640	580	390	Neg.	Neg.	4,220	4,030
Nov.	3,640	3,640	-	-	Neg.	Neg.	3,640	3,640
Dec.	3,640	3,640	-	-	Neg.	Neg.	3,640	3,640
Annual	43,680	43,680	58,170	38,790	Neg.	Neg.	101,850	82,470

2 1000 mw electric generating plants

Coal slurry 13 mmt/yr

Strip mine 73 mmt/yr

Irrigate 19,395 new acres

TABLE 44. Water requirements. Year 2000. Preliminary high scenario. Tongue River subbasin (42B&C).

Water Requirements (AF)

	Energy		Irrigation		Municipal		Total	
	Div.	Dep.	Div.	Dep.	Div.	Dep.	Div.	Dep.
Jan.	9,900	9,900	-	-	170	90	10,070	9,990
Feb.	9,900	9,900	-	-	170	90	10,070	9,990
Mar.	9,900	9,900	-	-	170	90	10,070	9,990
April	9,900	9,900	1,000	670	170	90	11,070	10,660
May	9,900	9,900	13,000	8,670	170	90	23,070	18,660
June	9,900	9,900	17,100	11,400	170	90	27,170	21,390
July	9,900	9,900	32,200	21,470	170	90	42,270	31,460
Aug.	9,900	9,900	25,150	16,770	170	90	35,220	26,760
Sept.	9,900	9,900	11,070	7,380	170	90	21,140	17,370
Oct.	9,900	9,900	1,000	670	170	90	11,070	10,660
Nov.	9,900	9,900	-	-	170	90	10,070	9,990
Dec.	9,900	9,900	-	-	170	90	10,070	9,990
Annual	118,800	118,800	100,520	67,030	2,040	1,080	221,360	186,910

3 1000 mw electric generating plants

1 250 mmcfd SNG plant

1 100,000 bbld syncrud plant

Coal slurry 36 mmt/yr

Strip mine 180 mmt/yr

Irrigate 33,500 new acres

TABLE 45. Water requirements. Year 2000. Preliminary low scenario. Mid-Yellowstone subbasin (42A&KJ).

Water Requirements (AF)

	Energy		Irrigation		Municipal		Total	
	Div.	Dep.	Div.	Dep.	Div.	Dep.	Div.	Dep.
Jan.	3,440	3,440	-	-	Neg.	Neg.	3,440	3,440
Feb.	3,440	3,440	-	-	Neg.	Neg.	3,440	3,440
Mar.	3,440	3,440	-	-	Neg.	Neg.	3,440	3,440
April	3,440	3,440	230	150	Neg.	Neg.	3,670	3,590
May	3,440	3,440	2,965	1,980	Neg.	Neg.	6,405	5,420
June	3,440	3,440	3,880	2,580	Neg.	Neg.	7,320	6,020
July	3,440	3,440	7,300	4,865	Neg.	Neg.	10,740	8,305
Aug.	3,440	3,440	5,700	3,800	Neg.	Neg.	9,140	7,240
Sept.	3,440	3,440	2,495	1,675	Neg.	Neg.	5,935	5,115
Oct.	3,440	3,440	230	150	Neg.	Neg.	3,670	3,590
Nov.	3,440	3,400	-	-	Neg.	Neg.	3,440	3,440
Dec.	3,440	3,400	-	-	Neg.	Neg.	3,440	3,440
Annual	41,280	41,280	22,800	15,200	Neg.	Neg.	64,080	56,480

1 1000 mw electric generating plant

1 250 mmcfd SNG plant

Strip mine 18.5 mmt/yr

Irrigate 7,600 new acres

TABLE 46. Water requirements. Year 2000. Preliminary intermediate scenario. Mid-Yellowstone subbasin (42A&KJ).

Water Requirements (AF)

	Energy		Irrigation		Municipal		Total	
	Div.	Dep.	Div.	Dep.	Div.	Dep.	Div.	Dep.
Jan.	5,560	5,560	-	-	85	40	5,645	5,600
Feb.	5,560	5,560	-	-	85	40	5,645	5,600
Mar.	5,560	5,560	-	-	85	40	5,645	5,600
April	5,560	5,560	750	500	85	40	6,395	6,100
May	5,560	5,560	9,750	6,500	85	40	15,395	12,100
June	5,560	5,560	12,750	8,500	85	40	18,395	14,100
July	5,560	5,560	24,000	16,000	85	40	29,645	21,600
Aug.	5,560	5,560	18,750	12,500	85	40	24,395	18,100
Sept.	5,560	5,560	8,250	5,500	85	40	13,895	11,100
Oct.	5,560	5,560	750	500	85	40	6,395	6,100
Nov.	5,560	5,560	-	-	85	40	5,645	5,600
Dec.	5,560	5,560	-	-	85	40	5,645	5,600
Annual	66,720	66,720	75,000	50,000	1,020	480	142,740	117,200

3 1000 mw electric generating plant

1 250 mmcfd SNG plant

Coal slurry 1017 mmt/yr

Strip mine 94 mmt/yr

Irrigate 25,000 new acres

TABLE 47. Water requirements. Year 2000. Preliminary high scenario. Mid-Yellowstone subbasin (42A&K).

Water Requirements (AF)

	Energy		Irrigation		Municipal		Total	
	Div.	Dep.	Div.	Dep.	Div.	Dep.	Div.	Dep.
Jan.	10,290	10,290	-	-	280	140	10,570	10,430
Feb.	10,290	10,290	-	-	280	140	10,570	10,430
Mar.	10,290	10,290	-	-	280	140	10,570	10,430
April	10,290	10,290	2,540	1,690	280	140	13,110	12,120
May	10,290	10,290	33,070	22,050	280	140	43,640	32,480
June	10,290	10,290	43,250	28,830	280	140	53,820	39,260
July	10,290	10,290	81,410	54,270	280	140	91,980	64,700
Aug.	10,290	10,290	63,600	42,400	280	140	74,170	52,830
Sept.	10,290	10,290	27,980	18,660	280	140	38,550	29,090
Oct.	10,290	10,290	2,550	1,700	280	140	13,120	12,130
Nov.	10,290	10,290	-	-	280	140	10,570	10,430
Dec.	10,290	10,290	-	-	280	140	10,570	10,430
Annual	123,480	123,480	254,400	169,600	3,360	1,680	381,240	294,760

3 1000 mw electric generating plants
2 250 mmcfd SNG plants
1 100,000 bbld syncrud plant
Coal slurry 32.7 mmt/yr
Strip mine 140 mmt/yr

Irrigate 84,800 new acres

TABLE 48. Water requirements. Year 2000. Preliminary intermediate scenario. Powder River subbasin (42I&J).

Water Requirements (AF)

	Energy		Irrigation		Municipal		Total	
	Div.	Dep.	Div.	Dep.	Div.	Dep.	Div.	Dep.
Jan.	1,300	1,300	-	-	Neg.	Neg.	1,300	1,300
Feb.	1,300	1,300	-	-	Neg.	Neg.	1,300	1,300
Mar.	1,300	1,300	-	-	Neg.	Neg.	1,300	1,300
April	1,300	1,300	1,950	1,300	Neg.	Neg.	3,250	2,600
May	1,300	1,300	25,350	16,900	Neg.	Neg.	26,650	18,200
June	1,300	1,300	33,150	22,100	Neg.	Neg.	34,450	23,400
July	1,300	1,300	62,400	41,600	Neg.	Neg.	63,700	42,900
Aug.	1,300	1,300	48,750	32,500	Neg.	Neg.	50,050	33,800
Sept.	1,300	1,300	21,450	14,300	Neg.	Neg.	27,750	15,600
Oct.	1,300	1,300	1,950	1,300	Neg.	Neg.	3,250	2,600
Nov.	1,300	1,300	-	-	Neg.	Neg.	1,300	1,300
Dec.	1,300	1,300	-	-	Neg.	Neg.	1,300	1,300
Annual	15,600	15,600	195,000	130,000	Neg.	Neg.	210,000	145,600

1 1000 mw electric generating plant
Coal slurry 1.67 mmt/yr
Strip mine 26.5 mmt/yr

Irrigate 65,000 new acres

TABLE 49. Water requirements. Year 2000. Preliminary high scenario. Powder River subbasin (42I&J).

Water Requirements (AF)

	Energy		Irrigation		Municipal		Total	
	Div.	Dep.	Div.	Dep.	Div.	Dep.	Div.	Dep.
Jan.	2,000	2,000	-	-	Neg.	Neg.	2,000	2,000
Feb.	2,000	2,000	-	-	Neg.	Neg.	2,000	2,000
Mar.	2,000	2,000	-	-	Neg.	Neg.	2,000	2,000
April	2,000	2,000	3,200	2,130	Neg.	Neg.	5,200	4,130
May	2,000	2,000	41,600	27,740	Neg.	Neg.	43,600	29,740
June	2,000	2,000	54,400	36,270	Neg.	Neg.	56,400	38,270
July	2,000	2,000	102,400	68,270	Neg.	Neg.	104,400	70,270
Aug.	2,000	2,000	80,000	53,340	Neg.	Neg.	82,000	55,340
Sept.	2,000	2,000	35,200	23,470	Neg.	Neg.	37,200	25,470
Oct.	2,000	2,000	3,200	2,130	Neg.	Neg.	5,200	4,130
Nov.	2,000	2,000	-	-	Neg.	Neg.	2,000	2,000
Dec.	2,000	2,000	-	-	Neg.	Neg.	2,000	2,000
Annual	24,000	24,000	320,000	213,350	Neg.	Neg.	344,000	237,350

1 1000 mw electric generating plant
Coal slurry 9.2 mmt/yr
Strip mine 40 mmt/yr

Irrigate 106,672 new acres

TABLE 50. Water requirements. Year 2000. Preliminary low scenario. Bighorn River subbasin (43P&O).

Water Requirements (AF)

	Energy		Irrigation		Municipal		Total	
	Div.	Dep.	Div.	Dep.	Div.	Dep.	Div.	Dep.
Jan.	60	60	-	-	Neg,	Neg.	60	60
Feb.	60	60	-	-	Neg.	Neg.	60	60
Mar.	60	60	-	-	Neg.	Neg.	60	60
April	60	60	255	170	Neg.	Neg.	315	230
May	60	60	3,315	2,210	Neg.	Neg.	3,375	2,270
June	60	60	4,335	2,890	Neg.	Neg.	4,395	2,950
July	60	60	8,160	5,440	Neg.	Neg.	8,220	5,500
Aug.	60	60	6,375	4,250	Neg.	Neg.	6,435	4,310
Sept.	60	60	2,805	1,870	Neg.	Neg.	2,865	1,930
Oct.	60	60	255	170	Neg.	Neg.	315	230
Nov.	60	60	-	-	Neg.	Neg.	60	60
Dec.	60	60	-	-	Neg.	Neg.	60	60
Annual	770	770	25,500	17,000	Neg.	Neg.	26,220	17,720

Irrigate 8,500 new acres

TABLE 51. Water requirements. Year 2000. Preliminary intermediate scenario. Bighorn River subbasin (BP&O).

Water Requirements (AF)

	Energy		Irrigation		Municipal		Total	
	Div.	Dep.	Div.	Dep.	Div.	Dep.	Div.	Dep.
Jan.	230	230	-	-	Neg.	Neg.	230	230
Feb.	230	230	-	-	Neg.	Neg.	230	230
Mar.	230	230	-	-	Neg.	Neg.	230	230
April	230	230	720	480	Neg.	Neg.	950	710
May	230	230	9,360	6,240	Neg.	Neg.	9,590	6,470
June	230	230	12,240	8,160	Neg.	Neg.	12,470	8,390
July	230	230	23,040	15,360	Neg.	Neg.	23,270	15,590
Aug.	230	230	18,000	12,000	Neg.	Neg.	18,230	12,230
Sept.	230	230	7,920	5,280	Neg.	Neg.	8,150	5,510
Oct.	230	230	720	480	Neg.	Neg.	950	710
Nov.	230	230	-	-	Neg.	Neg.	230	230
Dec.	230	230	-	-	Neg.	Neg.	230	230
Annual	2,760	2,760	72,000	48,000	Neg.	Neg.	74,760	50,760

Coal slurry 2 mmt/yr
Strip mine 26.5 mmt/yr

Irrigate 24,000 new acres

TABLE 52. Water requirements. Year 2000. Preliminary high scenario. Bighorn River subbasin (43P&O).

Water Requirements (AF)

	Energy		Irrigation		Municipal		Total	
	Div.	Dep.	Div.	Dep.	Div.	Dep.	Div.	Dep.
Jan.	1,740	1,740	-	-	Neg.	Neg.	1,740	1,740
Feb.	1,740	1,740	-	-	Neg.	Neg.	1,740	1,740
Mar.	1,740	1,740	-	-	Neg.	Neg.	1,740	1,740
April	1,740	1,740	3,050	2,050	Neg.	Neg.	4,790	3,790
May	1,740	1,740	39,650	26,650	Neg.	Neg.	41,390	28,390
June	1,740	1,740	51,850	34,850	Neg.	Neg.	53,590	36,590
July	1,740	1,740	97,600	65,600	Neg.	Neg.	99,340	67,340
Aug.	1,740	1,740	76,250	51,250	Neg.	Neg.	77,990	52,990
Sept.	1,740	1,740	33,550	22,550	Neg.	Neg.	35,290	24,290
Oct.	1,740	1,740	3,050	2,050	Neg.	Neg.	4,790	3,790
Nov.	1,740	1,740	-	-	Neg.	Neg.	1,740	1,740
Dec.	1,740	1,740	-	-	Neg.	Neg.	1,740	1,740
Annual	20,880	20,880	305,000	205,000	Neg.	Neg.	325,880	225,880

1 1000 mw electric generating plant
Coal slurry 5.2 mmt/yr
Strip mine 40 mmt/yr

Irrigate 102,382 new acres

TASK 6. INVESTIGATION OF EXISTING AND POTENTIAL IMPACTS OF COAL DEVELOPMENT ON WATER QUALITY. The Grantee shall perform five subtasks:

A) Gather and analyze water quality data for all significant surface waters in the area.

B) Investigate water quality problems directly associated with mining and energy conversion.

C) Investigate the adequacy of Montana's regulatory framework with respect to water pollution control.

D) Appraise the need for additional State water quality control efforts in view of the stresses of coal development.

E) Investigate the influences of stream dewatering on water quality.

ACTIVITIES DURING THE QUARTER

Field sampling during the quarter was restricted to a water quality run on the Yellowstone River from Corwin Springs to Cartwright, N.D., a cooperative effort partially funded by another contract. Seventeen complete samples and approximately 15 conductivity-only samples were obtained for analysis.

Linear regression equations were developed for the following:

1. Certain water quality parameters (e.g. Na, SO_4, SAR) as functions of conductivity, total dissolved solids, and discharge, for the Yellowstone River at Billings and at Miles City. For example, for the Yellowstone River at Billings:

   Na = 03.21875 + .1159 TDS (r = .9509)

   TDS = -.7576 + .6337 COND (r = .9941)

   HCO_3 = 500.0 - 95.83322 LOG FLOW (r = .9023)

   HCO_3 = 25.04338 + .50037 TDS (r = .9808)

   SAR = .21879 + .00281 TDS (r = .8722)

   SAR = .26476 + .02570 Na (r = .9711)

2. Conductivity as a function of discharge for the Little Bighorn River near Wyola and near Hardin. For example, for the Little Bighorn River near Wyola:

LOG COND = 3.38907 - .15578 LOG FLOW (r = .6617)

3. Sediment as a function of discharge for the Yellowstone River at Sidney, the Little Bighorn River near Hardin, the Little Bighorn River near Wyola, and the Bighorn River at Bighorn. For example, for the Little Bighorn River near Hardin:

   LOG SED LOAD = -6.14360 + 2.29983 LOG FLOW (r = .9259)

   LOG SED CONC. = -3.62959 + 1.38698 LOG FLOW (r = .8403)

   For the Yellowstone River near Sidney:

   SED LOAD = -1088.90674 + 2.73136 FLOW (r = .8763)

4. Conductivity for the Little Bighorn River near Hardin as function of conductivity of the Little Bighorn River near Wyola:

   LOG COND (Hardin) = -.07299 + 1.06776 LOG COND (Wyola) (r = .9483)

5. Sediment for the Little Bighorn River near Hardin as function of sediment of the Little Bighorn River near Wyola:

   LOG SED CONC (Hardin) = -.04425 + 1.11408 LOG SED CONC (Wyola) (r = .8845)

   LOG SED LOAD (Hardin) = -.16002 + 1.15296 LOG SED LOAD (Wyola) (r = .9468)

No consistent temperature-flow relationship is evident from any analysis performed thus far. The USGS is developing a temperature model of the Yellowstone River that may be available for this project.

Table 53, compiled during the quarter, summarizes the historical total dissolved solids concentrations for selected stations in the lower Yellowstone River Basin.

A legal study to evaluate and review the State of Montana's legal framework regarding water quality was completed and is currently being reviewed by the Department of Health's legal division. Consequently, no results are available for publication at this time.

Preliminary analyses of the effects of the development scenarios on water quality were performed for the Tongue and Bighorn rivers. Results are discussed below.

TABLE 53. Average Monthly Total Dissolved Solids: in mg/l (top number) and in thousands of tons.

STATION	O	N	D	J	F	M	A	M	J	J	A	S	Average Annual	Period of Record
Yellowstone River	273	285	300	312	294	286	253	146	117	124	203	261	178	1951-58
at Billings	88.8	84.0	73.3	67.7	64.2	72.6	85.6	162.0	256.9	163.0	102.7	88.4	1309.2	1964-69
Bighorn River	589	544	560	543	577	596	575	583	580	499	414	448	548	1970-74
near St. Xavier	192.5	188.8	172.5	165.5	165.7	192.9	198.4	228.9	296.9	220.2	104.5	110.3	2237.1	
Little Bighorn R.	347	352	357	366	365	434	410	285	219	284	242	348	306	1970-74
below Pass Creek	4.28	4.02	3.56	3.63	4.37	6.48	9.10	15.26	16.08	6.63	4.11	4.20	81.72	
nr. Wyola														
Little Bighorn R.	458	480	497	483	452	555	594	447	287	384	440	430	436	1970-74
near Hardin	8.25	7.96	5.81	6.99	11.0	25.8	24.8	32.6	27.8	10.4	6.54	7.36	175.3	
Bighorn River	751	768	767	717	703	712	765	613	491	504	695	765	655	1951-69
at Bighorn	192.5	186.4	188.9	163.7	156.0	191.0	192.1	205.4	297.0	228.0	142.6	167.0	2310.6	
Yellowstone River	427	487	477	493	482	485	482	336	205	249	330	376	346	1969-74
at Miles City	348.0	357.0	268.8	263.5	296.4	411.5	384.7	530.9	635.0	487.0	254.0	226.5	4463.3	
Tongue River at	472	485	525	494	492	548	533	251	200	306	500	457	3[illegible]9	1966-70
State Line	11.3	10.6	9.22	8.00	9.43	19.0	18.7	28.1	33.6	14.7	8.61	9.92	1[illegible].2	
Tongue River	530	616	718	694	531	446	524	456	282	339	459	479	436	1951-69
at Miles City	8.93	11.1	10.6	9.78	9.84	18.6	21.8	23.8	30.7	12.3	7.96	7.39	172.8	
Powder River	1491	1474	1675	1724	1098	795	1125	1107	1095	1217	1627	1342	1123	1951-62
at Locate	13.2	14.2	18.1	13.0	21.4	65.0	57.8	71.4	105.1	46.5	27.2	12.3	465.2	
Yellowstone River	554	580	633	637	568	504	558	370	286	292	430	534	421	1951-69
near Sidney	351.7	339.7	309.4	294.9	293.9	422.7	446.3	485.1	857.7	534.4	276.4	289.3	4901.5	

PRELIMINARY IMPACTS

METHODOLOGY

Preliminary analyses were completed for the Tongue and Bighorn subbasins. The underlying principle governing the analyses is that mass must be conserved; in this case, the conservation-of-mass concept is applied to the water and the salt which is dissolved in, and moves with, the water. The net salt load is equal to the original salt in the stream minus salt removed with diversions plus salt in return flows to the stream. For energy diversions it was assumed that no water or salt would return to the stream. For irrigation it was assumed that all salt in the original diversions would return to the stream; otherwise, salt would accumulate in the soil profile and eventually reduce or eliminate crop yields. With an ideal irrigation system, salt balance will be maintained, i.e., salt brought to the soil in irrigation water will be removed in the return waters. Since the ideal system is seldom realized, it is common practice to "overirrigate," forcing more water over and through the soil than is needed to grow the crop and maintain a salt balance.

No field studies have been reported in Montana in which salt loads from irrigated land were measured. Unpublished data from the Bureau of Reclamation (Madsen 1975) for the Bighorn River in Wyoming indicated a salt dissolution of from 0.8 to nearly 7 tons per acre where diversions were on the order of 6 acre-feet per acre. Anticipating diversions of 3 acre-feet per acre for new irrigated land, an assumed salt dissolution of 1 ton per acre was used for computations in this study. Results of a total water management study now being conducted by the Bureau of Reclamation in the Yellowstone River Basin will yield more accurate figures for salt dissolution. It is not known if that study will be completed soon enough to be incorporated in analyses for this project.

The temporal distribution of irrigation return flows is also unknown. A general distribution taken from data used by the Bureau of Reclamation and reported by the Montana Department of Natural Resources and Conservation (1975b) was used.

RESULTS

Bighorn River

The State Water Planning Model was used to simulate the effects of the three scenarios on flow at the mouth of the Bighorn River. Historical flow and quality records and the conservation-of-mass concept were employed to determine changes in water quality. Results are summarized in table 54.

Average annual concentrations of TDS (total dissolved solids) were increased 1.8 percent, 3.7 percent, and 14 percent over historical median values for the low, intermediate, and high scenarios, respectively. Similarly, 90 percentile values increased 7.2 percent, 11 percent, and 30 percent. Examination of monthly median values reveals no significant problems except for August and September, high scenario, when TDS concentrations are at levels (1166 and 918 mg/l) which could restrict use of the water for irrigation for some combinations of crops and soils.

TABLE 54. Total dissolved solids (mg/l), Bighorn River at Bighorn, State Water Planning Model Scenarios.

Month	Median Values				90 Percentile Values			
	Historical	Low	Intermediate	High	Historical	Low	Intermediate	High
Oct.	770	756	768	827	910	932	954	1050
Nov.	805	759	767	806	905	989	1005	1075
Dec.	855	823	830	863	1110	1007	1019	1072
Jan.	780	773	779	809	875	886	897	944
Feb.	760	752	756	776	865	834	841	871
Mar.	765	747	752	774	860	875	885	927
April	800	793	800	831	890	877	889	943
May	600	607	619	691	730	853	898	1177
June	475	505	516	571	600	640	677	895
July	560	560	580	715	630	971	1162	3391
Aug.	750	771	813	1166	840	970	1080	3369
Sept.	790	799	816	918	880	961	1001	1239
Annual	671	683	696	766	825	884	915	1072

Problems would be more severe for 90-percentile values. July, August, and September TDS concentrations progressively worsen under all three scenarios. Use of the water for irrigation would be restricted under low and intermediate scenarios; under the high scenario, water would be unusable during July and August when TDS would exceed 3300 mg/l.

Water with TDS concentrations between 500 and 1500 mg/l is classified as "high-salinity" water which cannot be used on soils with restricted drainage. TDS greater than 1500 mg/l characterizes a "very high-salinity water", not suitable for irrigation under ordinary conditions. It can be used on well drained soils, but more water must be applied to provide adequate leaching, and salt-tolerant crops must be grown (Richards 1954). Sugar beets, wheat, and barley, typical crops in the lower Bighorn Valley, are salt-tolerant and probably would be only slightly affected by an occasional application of high-salinity water. Yields of corn and alfalfa, less tolerant to salts, could be reduced significantly by application of water with TDS concentrations corresponding to those of the high scenario, 90-percentile values.

The toal annual salt load of the Bighorn River is not changed dramatically under any scenario for either median or 90-percentile values (table 55). The increased concentrations, however, will tend to increase the TDS of the Yellowstone River below Bighorn. This increase will be quantified in the future.

TABLE 55. Annual total dissolved solids, Bighorn River at Bighorn, State Water Planning Model Scenarios

	Median Values				90 Percentile Values			
	Hist.	Low	Int.	High	Hist.	Low	Int.	High
Aver. Annual TDS in:								
mg/l	671	683	696	766	825	884	915	1072
tons	2392400	2395100	2408600	2469400	1476500	1555100	1568100	1624800

This analysis used historical records which will not reoccur in the future because of the construction of Yellowtail Dam in the mid-1960's. If historical records were adjusted to reflect the regulating effect of storage behind Yellowtail, changes in TDS would probably not be as severe during the summer months. HYD2 simulation of the Bighorn will measure the effect of Yellowtail and provide for a more realistic appraisal of water quality at the mouth of the river. The HYD2 simulation will be analyzed during the next quarter.

Tongue River

Table 56 summarizes the TDS values for the Tongue River at Miles City resulting from use of the State Water Planning Model, historical flow-quality records, and the conservation-of-mass principle. Annual average median TDS concentrations would be increased 7.5 percent and 76 percent by the low and

intermediate scenarios, respectively. Corresponding increases for the 90-percentile values are 6.3 percent and 144 percent. Concentrations were not computed for the high scenario because the stream would be essentially dry at Miles City; flow would consist only of concentrated irrigation return flows.

The monthly values of TDS have not yet been satisfactorily determined. Preliminary analysis indicates that irrigation-season TDS concentrations may be too high for use under both low and intermediate scenarios at the 90 percentile levels and under the intermediate scenario at median levels.

The increase in concentration of Tongue River water will, of course, tend to increase the concentration in the Yellowstone below Miles City.

TABLE 56. Annual total dissolved solids, Tongue River at Miles City, State Water Planning Model Scenarios

	Median Values				90 Percentile Values			
	Hist.	Low	Int.	High*	Hist.	Low	Int.	High*
Annual Aver. TDS in:								
mg/l	452	486	797	---	624	663	1523	---
tons	177800	180400	140200	---	70000	85500	94400	---

* High-scenario flows consist only of irrigation return flows which are highly saline. Values for TDS have not been estimated.

ACTIVITIES PLANNED FOR NEXT QUARTER

The principal activity for next quarter wll be a calculation of salinity levels under the three scenarios for additional subbasins. A description of baseline water quality for subbasins below Billings will be begun.

Task 6 is approximately 65% complete.

TASK 7. INVESTIGATION OF WATER-BASED RECREATION ON THE YELLOWSTONE RIVER. The Grantee shall perform three subtasks:

A) Compile and review current recreation usage of the Yellowstone study area in terms of volume, type, and geographic location.

B) Assess the impact of altered stream flows on current and potential recreation uses.

C) Conduct a field evaluation of alternative and additional recreation sites with potential for water-based recreation.

INTRODUCTION

This quarterly report is designed to present: 1) a remaining portion of the 1975 summer recreational use data; and 2) the 1975 autumn recreational use data; 3) the 1975-76 winter recreational use data; 4) a few alternative sites with potential for water-based recreation; and 5) a preliminary assessment of altered streamflows on extant and potential recreational uses, by river section.

OBSERVATIONS OF WATER-BASED RECREATIONAL USE

SUMMER AND EARLY AUTUMN USE

Garbage Weight Data and Car Counter Use

The vastness of the Yellowstone study area has not permitted detailed documentation of tributary recreational use to date. However, at some tributary recreational sites, car counters were present and/or garbage was collected and weighed by Montana Department of Fish and Game caretakers (figure 20). For six of these areas, correlations can be made from garbage weight and car counter data (table 57).

TABLE 57. Number of persons per pound of garbage.

River	Area	Months	Number of Cars	No. Persons Per Auto	# of Garbage	Persons/ Pound
Stillwater	Buffalo Jump F.A.	June-Nov.	1779	2.31	4063	1.01
Stillwater	Cliff Swallow F.A.	June-July	430	2.31	2167	.46
Stillwater	Castle Rock F.A.	June-Nov.	1325	2.31	3522	.87
Stillwater	White Bird F.A.	July-Aug.	600	2.31	1199	1.16
Stillwater	Fireman's Point F.A.	August	489	2.31	730	1.55
Yellowstone	Indian Fort F.A.	Sept.-Nov.	1035	2.31	1035	2.31

A. STILLWATER RIVER

1. Fireman's Point F.A.*
2. Swinging Bridge F.A.
3. White Bird F.A.*
4. Absoroka F.A.
5. Cliff Swallow F.A.*
6. Castle Rock F.A.*
7. Moraine F.A.
8. Buffalo Jump F.A.*
9. Rosebud Isle F.A.

B. CLARKS FORK RIVER

No Data Collected

C. BIG HORN RIVER

No Data Collected

D. TONGUE RIVER

No Data Collected

E. POWDER RIVER

No Data Collected

YELLOWSTONE RIVER

10. Indian Fort F.A.*
11. Itch-Kep-Pe F.A.
12. East and West Rosebud R.A.

MISCELLANEOUS

13. Cooney Dam R.A.
14. Makoshika S.P.

* - Denotes car counter use

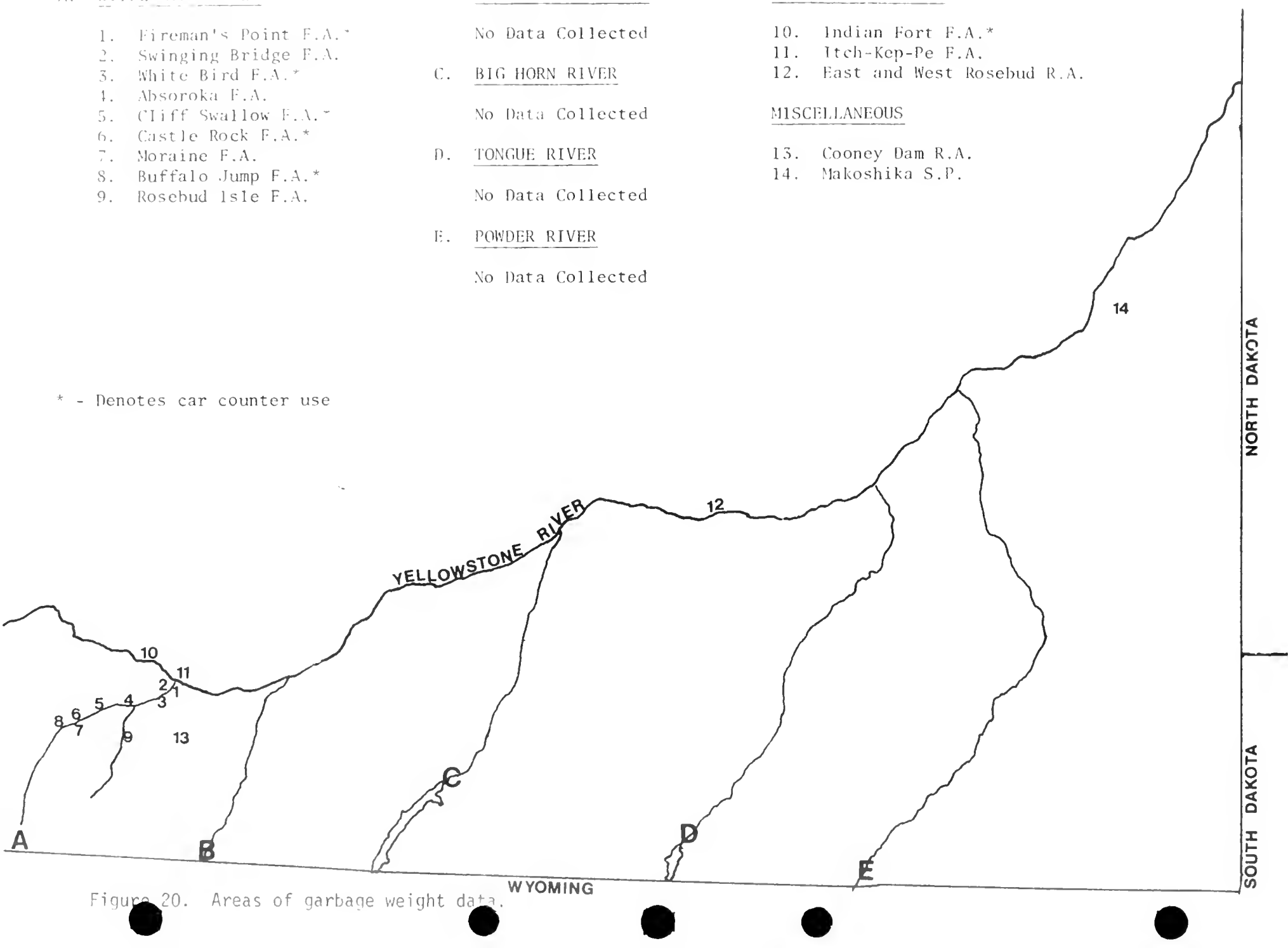


Figure 20. Areas of garbage weight data.

The number of persons per car, i.e. the total number of observed recreationists divided by the total number of observed automobiles, was derived from data collected during the summer recreational survey along the Yellowstone. Data can be collected during the same periods of 1976 and similar ratios used to determine significant use increases or decreases. An interesting note here is that Indian Fort Fishing Access, the only area of the mainstem Yellowstone River included in the data, showed the greatest number of persons per pound. The 1975 summer recreational study revealed that for the westernmost section of the study area, which includes Indian Fort Fishing Access, 33.3 percent of 39 valid observations noticed an increased litter problem and 56.7 percent of 60 valid responses listed the length of stay as day use only. Thus, recreationists may be negligent in placing litter in the proper containers and/or the amount of potential litter was reduced due to the prevalence of one-day outings.

Garbage weights for separate areas have been tabulated (but are not presented here) for future reference, pending the collection of similar 1976 data. Significant differences appear between areas, but to date, no conclusions can be drawn due to the lack, for comparison, of valid recreational use data, car-counter tabulations, or total observed random use.

Aerial Censuses

From August 8 through December 5, 1975, 29 aerial flights were completed by various Region 7 Montana Department of Fish and Game personnel. The average length of these round-trip flights was 2.67 hours, and the average recreationist siting per flight was 17.3. The majority (27) of the flights were made on weekdays. The various distances and directions flown dictate a breakdown of each flight into small subsections; thus, each flight was counted as one observation of each of several sections of the river (figure 21). Recreational pursuits were broken down into five usually definable categories: fishing, big game or bird hunting, waterfowl hunting, rest and relaxation, and agate hunting (table 58). The number of boats was also recorded. Big game hunting and bird (mostly pheasant) hunting were combined due to the similar, indirect role of the Yellowstone River in these sports.

Hunting was the most frequently observed activity in all sections except 4A, 4B, and 5. The flight period included all of the 1975 big game and bird hunting season, which began October 19 and closed November 11. Agate hunting in these same sections was also very popular. Within sections 1, 2 and 3, the preponderance of low stream gradient and large flood plain creates an ideal whitetail deer and pheasant habitat. In addition, the presence of many large islands increases the chance of success of hunters and rock hounds. Boats are used extensively in these activities, but boat launching opportunities are inadequate in section 2, possibly explaining the data obtained there.

Waterfowl hunting data were limited to the flood plain; thus recreationists hunting in fields and along small tributary hunters were not observed. Waterfowl hunting success, however, is not determined only by the condition of the Yellowstone River itself, but also by other factors such as the yearly climatic conditions of the region. Migratory waterfowl are more abundant during certain portions of the season than others.

Section: 1A. North Dakota line to Seven Sisters Game Management Area

1B. Seven Sisters Game Management Area to Glendive

1C. Glendive to the mouth of the Powder River

2 . The mouth of the Powder River to the mouth of the Tongue River

3A. The mouth of the Tongue River to Forsyth

3B. Forsyth to the mouth of the Bighorn River

4A. The mouth of the Bighorn to Billings

4B. Billings to the mouth of the Clarks Forks

5 . The mouth of the Clarks Fork to Big Timber

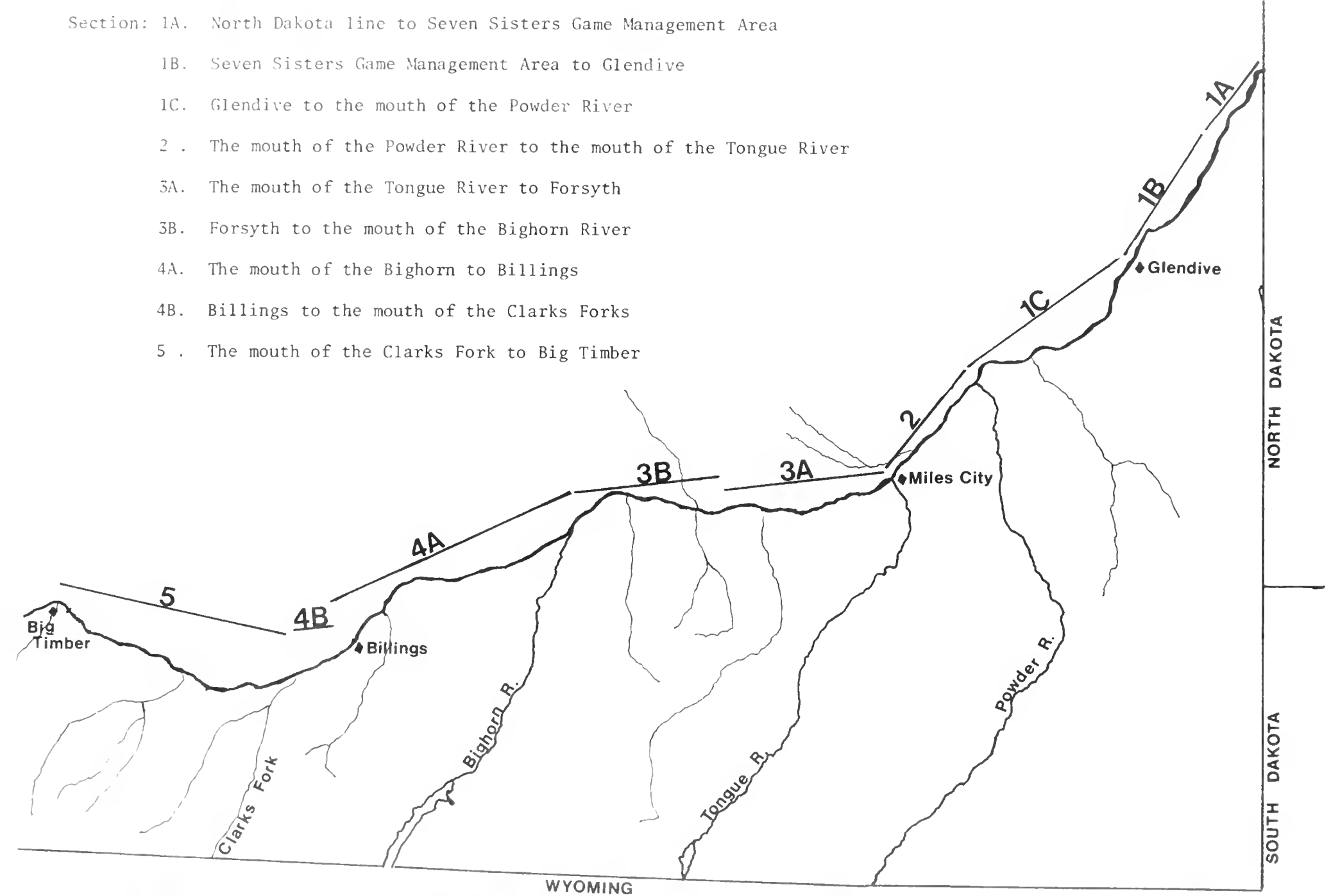


Figure 21. Aerial census sections.

TABLE 58. Aerial observations of recreational activities.

	Number of Recreationists									
SECTION	FISHING	BIG GAME HUNTING OR BIRD HUNTING	WATERFOWL HUNTING	REST AND RELAXATION (UNIDENTIFIABLE)	AGATE HUNTING	TOTAL	NUMBER OBSERVATIONS	NUMBER PEOPLE PER OBSERVATION	BOATS	NUMBER PERSONS PER BOAT
1A	3	17	3	2	6	31	11	2.82	3	10.3
1B	17	40	3	0	35	95	10	9.50	10	9.5
1C	5	43	4	2	25	79	9	7.22	5	15.8
2	12	22	3	0	14	51	11	3.18	3	17.0
3A	28	40	8	14	19	109	14	7.79	12	9.9
3B	6	18	8	12	2	46	14	3.28	3	15.3
4A	30	20	14	8	13	85	15	5.66	6	14.2
4B	8	1	0	0	0	9	5	1.80	1	9.0
5	2	0	0	0	0	2	3	.66	0	0
TOTAL	111	201	43	38	114	507	82		43	

Recent Waterfowl Hunting Pressure

Substantiation of irregular waterfowl hunting pressure is seen from the 1971-through-1974 Montana Department of Fish and Game waterfowl hunting questionnaire data (table 59). Subsamples of hunting pressure were obtained within each county in the study area, and the numbers of duck and goose hunters per day were calculated. Also, the mean flow of the Yellowstone River at Sidney was calculated for October, November, and December (table 59).

Most notable of the factors which affect waterfowl hunting pressure are lengths of seasons, coincidence with other hunting seasons, federal regulations governing bag limits and shooting hours, the amount of leisure time during seasons (the 1974 season had 26 weekend or holiday days while the 1972 season had only 20), weather conditions, and state regulations. All of these factors may vary annually.

WINTER RECREATIONAL USE

Personal Observation and Communication

Although no use studies were undertaken during the winter of 1975-1976, observations, communications, and common sense play a major role in evaluation. River ice and inclement weather drastically reduce recreational use of the Yellowstone River; the majority of winter outdoor recreationists prefer to engage in various other forms of recreation such as snowmobiling, predator hunting and trapping, and farm pond ice fishing.

River ice began to accumulate in mid-December of 1975. The Yellowstone River within the study area usually is not completely ice-covered, but shoreline ice is dangerous and inhibits access to the river by recreationists.

Complete ice breakup usually occurs first on the uppermost reaches of the study area, with large ice jams often occurring within the Glendive-Sidney segment of the Yellowstone. As the river clears, water-based recreation follows. Angler success increases with the spawning runs of various species, which, depending upon weather conditions, can occur from late winter to mid-spring.

POTENTIAL RECREATION

Preliminary investigations of alternative potential sites have been based on need and feasibility. Summer survey results indicate that most people (82.6%) would like to see another site within at least 30 miles of the one currently enjoyed. The nature of alternative sites may not allow all recreational interests to be pursued at each, but important access would be provided. Along the Yellowstone River, four areas have been investigated: 1) an area north of Rosebud, T6N, R42E, S16; 2) a state section near the mouth of Sunday Creek, T9N, R48E, S36; 3) a section near the mouth of the Powder River, T11N, R50E, S4; and 4) a large area of 14,000 acres near Intake, including part of all of sections 1, 2, 10, 11, 12, 13, 14, 20, 21, 22, 23, 24, 25, 26, 27, 28 and 33 in T18N, R57 and sections 7, 17, 18, 19 and 30 in T18N, R58E. In addition, other possible

TABLE 59. County waterfowl data, 1971-1974.

County	Duck Hunters	Duck Days	$\frac{DH}{DD}$	No.Goose Hunters	Goose Days	$\frac{GH}{GD}$	Mean Flow (CFS) Oct.Nov.Dec
Big Horn							
1971	606	90	6.73	329	90	3.66	8,244
1972	806	90	8.96	445	90	4.94	11,004
1973	704	76	9.26	418	93	4.49	9,986
1974	263	64	4.11	121	93	1.30	9,517
Carbon							
1971	246	90	2.48	82	90	.91	8,244
1972	303	90	3.37	56	90	.62	11,004
1973	234	76	3.08	71	93	.76	9,986
1974	223	64	3.48	40	93	.43	9,517
Carter							
1971	20	90	.22	0	90	0	8,244
1972	9	90	.10	9	90	.10	11,004
1973	20	76	.26	0	93	0	9,986
1974	40	64	.63	0	93	0	9,517
Custer							
1971	246	90	2.73	154	90	1.71	8,244
1972	246	90	2.73	189	90	2.10	11,004
1973	234	76	3.08	255	93	2.74	9,986
1974	131	64	2.05	192	93	2.06	9,517
Dawson							
1971	164	90	1.82	82	90	.91	8,244
1972	284	90	3.16	132	90	1.47	11,004
1973	163	76	2.14	122	93	1.31	9,986
1974	243	64	3.80	152	93	1.63	9,517

TABLE 59.(continued).

County	Duck Hunters	Duck Days	DH/DD	Goose Hunters	Goose Days	GH/GD	Mean Flow (CFS) Oct.Nov. Dec.
Fallon							
1971	92	90	1.02	31	90	.34	8,244
1972	9	90	.10	18	90	.19	11,004
1973	61	76	.80	10	93	.11	9,986
1974	50	64	.78	20	93	.22	9,517
Powder River							
1971	20	90	.22	0	90	0	8,244
1972	28	90	.31	9	90	.10	11,004
1973	0	76	0	10	93	.11	9,986
1974	20	64	.31	0	93	0	9,517
Prairie							
1971	20	90	.22	0	90	0	8,244
1972	28	90	.31	56	90	.62	11,004
1973	51	76	.67	40	93	.43	9,986
1974	60	64	.94	81	93	.87	9,517
Richland							
1971	246	90	2.73	62	90	.69	8,244
1972	322	90	3.58	151	90	1.62	11,004
1973	295	76	3.88	122	93	1.31	9,986
1974	284	64	4.44	202	93	2.17	9,517
Rosebud							
1971	154	90	1,71	175	90	1.94	8,244
1972	170	90	1.89	218	90	2.42	11,004
1973	214	76	2.82	163	93	1.75	9,986
1974	81	64	1.27	162	93	1.74	9,517

TABLE 59.(continued).

County	Duck Hunters	Duck Days	DH/DD	Goose Hunters	Goose Days	GH/GD	Mean Flow (CFS) Oct. Nov. Dec.
Sweetgrass							
1971	103	90	1.14	31	90	.34	8,244
1972	113	90	1.26	170	90	1.89	11,004
1973	132	76	1.74	51	93	.55	9,986
1974	152	64	2.38	71	93	.76	9,517
Stillwater							
1971	113	90	1.26	41	90	.46	8,244
1972	256	90	2.84	170	90	1.89	11,004
1973	183	76	2.41	91	93	.98	9,986
1974	202	64	3.16	142	93	1.53	9,517
Treasure							
1971	113	90	1.26	113	90	1.26	8,244
1972	132	90	1.47	123	90	1.37	11,004
1973	71	76	.93	193	93	2.08	9,986
1974	172	64	2.69	243	93	2.61	9,517
Yellowstone							
1971	924	90	10.27	339	90	3.77	8,244
1972	1,034	90	11.49	436	90	4.84	11,004
1973	1,224	76	16.11	561	93	6.03	9,986
1974	1,024	64	16.00	527	93	5.67	9,517
Wibaux							
1971	113	90	1.26	0	90	0	8,244
1972	18	90	.20	0	90	0	11,004
1973	10	76	.13	0	93	0	9,986
1974	20	64	.31	0	93	0	9,517

sites not investigated during the quarter are the Howrey ranch adjacent to the Montana Fish and Game Isaac Homestead Game Management area, the Lyle Pettus ranch 10 miles east of Miles City, and two small 4-5 acre tracts, one north of Terry just off U.S. Highway 253 and another near Fallon, Montana.

Priorities and recreational potential will not be discussed until further investigation can be made. Boat launching potential is a major criteria for evaluation; many areas will receive lower priority than others if this potential does not exist.

PRELIMINARY IMPACT ASSESSMENTS

CRITERIA

Preliminary impact assessments for the three development scenarios, high, medium, and low, will be discussed by section (figure 21). To date, the mainstem Yellowstone River scenarios are limited to only one location, near Rosebud, Montana. Thus, accuracy of even preliminary assessment will be highest within section three, 110.6 river miles from the mouth of the Tongue River to the mouth of the Bighorn River.

Impact assessment is based upon a matrix system comprised of a list of recreational activities, sectional rating preferences for each activity based on the recreational use observed during the summer of 1975, and an impact modification number for each activity. Within each section, popularity of various activities was calculated by percentages (table 60). A sectional rating preference of one (1) signifies from 0 to 5 percent participation; two (2), 6 to 15 percent; and three (3), above 15 percent. This sectional rating preference is multiplied by the impact modification number, a minus one (-1) if recreational potential would be reduced, a zero (0) if there would be no effect, or a (+1) if recreational potential would be enhanced. Products of the sectional rating preference and impact modification number are added for each scenario and overall effects compared for each section and scenario. Reliance on summer use data is based on the fact that summer is the highest water-based recreational use season and that water consumption requirements are often greatest during the summer for all types of water use, including energy-related uses.

The impact modification numbers (IMN) incorporate many factors, some of which cannot be measured within the scope of this study. For example, in section 3, of 45 valid responses, 57.8 percent noted that insects had reduced the time spent enjoying various recreational activities. Thus, insect (especially mosquito) population changes could lead to a different impact modification number. Other examples are bird watching and sightseeing, both of which are reliant on the habitat types of the Yellowstone River flood plain. If noticeable alterations in these habitat types occur, aesthetic values might be diminished. IMN values could increase, however, if the amount of irrigated land was to increase. Waterfowl and pheasants might benefit, raising several IMN's, especially those related to hunting. IMN's for various activities have not taken these unmeasured factors into account.

Accuracy can be enhanced in the future as more locations for development or impact are identified within each section.

TABLE 60. Percentages of activities within each section.

Activity	Section 1	Section 2	Section 3	Section 4	Section 5
Swimming	0	0	0	23.1	.6
Picnicking	0	0	8.5	1.1	21.9
Rest & Relaxation	17.1	55.7	17.3	16.8	23.8
Boating-Floating	17.1	33.2	12.4	8.0	8.0
Horseback Riding	0	0	.5	0	1.2
Bicycling	0	0	.5	2.2	1.2
Motor Biking	4.3	1.2	1.0	3.0	2.1
Driving for Pleasure	0	0	5.9	5.5	1.2
Playing Outdoor Games	4.3	0	5.4	1.4	10.3
Rock Hounding	11.4	3.2	8.0	0	2.4
Sightseeing	5.0	0	8.3	18.5	8.8
Walking for Pleasure	0	0	1.0	.3	.9
Waterskiing	0	0	0	0	0
Birdwatching	0	0	0	0	0
Fishing	40.8	6.7	31.2	20.1	17.6

Interactions among recreational activities (e.g. floating and sightseeing) occur within all sections, but are not considered. Totals among the interactions can be compared to the standard zero value, however. Thus, deviations from zero may induce a higher or lower level of satisfaction derived from combined activities. For example, the Miles City Agate Club has approximately 60 members, 14 of whom reported 47 total visits a year between Miles City and Terry (section 2). Averaging a five-hour trip per day, 11 people used boats or rafts. Thus, boating (-3) is added to rock hounding (+1), sightseeing (-1) and access (+3) and the total trip achieved the norm, zero. Achieved levels of satisfaction under the high scenario conditions were approximately the same, theoretically, as in the "good old days" a few years before.

SECTION 3

The matrix of table 61 shows the overall effect of each scenario on water-based recreation in section 3. Preliminary investigation shows that the intermediate scenario would benefit the recreational potential, the low scenario would have no effect, and the high scenario would produce a small negative effect.

It is important to note that fishing success is an unknown factor. From personal observation, communication, and survey data, fishing success draws people to an area, but a large percentage (48.6) of fishermen in section 3 were unsuccessful. Fishing success can be listed as a separate, intangible factor that differs from the physical act of fishing itself, which many people enjoy immensely, regardless of the take-home product.

The low scenario is close enough to existing situations that noticeable effects are not expected.

The intermediate scenario would affect access which has been classified separately from recreational activity. This scenario compiled the highest preliminary benefit rating due to access improvement during the summer months.

The high scenario received a preliminary negative impact assessment because, in spite of an improved access situation, waterskiing, boating and floating received greater combined negative values due to increased obstacles and to two or three marginal riffle areas where, in low water years, definite problems would arise with water depth. Rock hounding was given a positive value due to the increased amount of rocks available and visible; this benefit would perhaps be temporary, however, because of the need for flood waters and ice scouring to expose new agates.

SECTION 2

From the mouth of the Powder River, which is included in section 2, to the mouth of the Tongue River, which is not, there are 35.5 river miles. Access is limited and the Department of Fish and Game owns no area or access within this section.

Table 62 shows the estimated effect of each scenario on water-based recreation in section 2. The only difference between values obtained for section 3 and section 2 is that the sectional rating preference for rockhounding was reduced to a 1 in section 2 due to a smaller percentage of observed participation there.

SECTION 1

This section is the most easterly in the study area and stretches 149.5 river miles from the Montana-North Dakota state line to the mouth of the Powder River (which is not included). The river gradient in this section is generally the lowest in the study area.

Table 63 shows the estimated effect of each scenario on water-based

TABLE 61. Preliminary impact assessment for section 3.

Activity	Sectional Rating Preference	Impact Modification Number		
		High Scenario	Intermediate Scenario	Low Scenario
Swimming	1	0	0	0
Picnicking	2	0	0	0
Rest ¢ Relaxation	3	0	0	0
Boating	2	-1	0	0
Floating	1	-1	0	0
Horseback Riding	1	0	0	0
Bicycling	1	0	0	0
Motor Biking	1	0	0	0
Driving for Pleasure	2	0	0	0
Playing Outdoor Games	2	0	0	0
Rock Hounding	2	+1	0	0
Sightseeing	2	-1	0	0
Walking for Pleasure	1	0	0	0
Waterskiing	1	-1	0	0
Bird Watching	1	0	0	0
Fishing	3	0	0	0
Fishing Success	3*	Unknown	Unknown	Unknown
Access	3	+1	+1	0
Totals		-1	+3	0

TABLE 62. Preliminary impact assessment for section 2.

Activity	Sectional Rating Preference	Impact Modification Number		
		High Scenario	Medium Scenario	Low Scenario
Swimming	1	0	0	0
Picnicking	1	0	0	0
Rest and Relaxation	3	0	0	0
Boating	3	-1	0	0
Floating	1	-1	0	0
Horseback Riding	1	0	0	0
Bicycling	1	0	0	0
Motor Biking	1	0	0	0
Driving for Pleasure	1	0	0	0
Playing Outdoor Games	1	0	0	0
Rock Hounding	1	+1	0	0
Sightseeing	1	-1	0	0
Walking for Pleasure	1	0	0	0
Waterskiing	1	-1	0	0
Bird Watching	1	0	0	0
Fishing	2	0	0	0
Fishing Success	2	Unknown	Unknown	Unknown
Access	3	+1	+1	0
Total		-2	+3	0

TABLE 63. Preliminary impact assessment for section 1.

Activity	Sectional Rating Preference	Impact Modification Numbers: High Scenario	Medium Scenario	Low Scenario
Swimming	1	0	0	0
Picnicking	1	0	0	0
Rest & Relaxation	3	0	0	0
Boating	3	-1	0	0
Floating	1	-1	0	0
Horseback Riding	1	0	0	0
Bicycling	1	0	0	0
Motor Biking	1	0	0	0
Driving for Pleasure	1	0	0	0
Playing Outdoor Games	1	0	0	0
Rock Hounding	2	+1	0	0
Sightseeing	1	-1	0	0
Walking for Pleasure	1	0	0	0
Waterskiing	1	-1	0	0
Birdwatching	1	0	0	0
Fishing	3	0	0	0
Fishing Success	3	Unknown	Unknown	Unknown
Access	3	+1	+1	0
Totals		-1	+3	0

recreation in section 1. As in section 3, the high scenario receives a small negative value, the intermediate scenario a positive value, and no effect was estimated from the low scenario.

In section 1, fishing for pike, paddlefish, and catfish is extremely popular. Paddlefishing popularity is highest during late spring, notably Memorial Day, and early summer. As spring runoff produces high flows and turbidity, the paddlefish run up the Yellowstone River is somewhat slowed by a diversion dam at Intake, Montana, site of a Montana Fish and Game Fishing Access Site. Observations obtained at this dam, combined with others near Forsyth, Waco, and Huntley, indicate abnormally high fishing pressure for this particular species. An increase in the number of these dams could reduce angler concentration levels, but increase the difficulty of fish migration.

ACTIVITIES PLANNED FOR NEXT QUARTER

Activities for the next quarter include emphasis on spring recreational use and collection of more scenario and boat registration data.

Task 7 is approximately 75% completed.

TASK 8. INVESTIGATION OF ALTERED STREAMFLOWS ON CHANNEL PROCESSES AND DYNAMICS. The Grantee shall study stream channel processes and dynamics at various discharge rates to determine the effect of stream flow alterations on stream stage and channel stabilization. The Grantee shall provide hydrologic expertise for investigators engaged in other tasks set forth in this article.

VIGIL NETWORK SYSTEM

ACTIVITIES DURING THE QUARTER

This quarter's activities were confined to data processing and preparation of the final vigil network files for 22 stations. This work is nearly complete, lacking only a few final photographs and final review. The Vigil Network files are now in standard format, all field plane table sheets are redrafted and xero-reduced, all field notes are typed in standard formats, and photo and biological sample stations are noted on maps and tabulated. Proof sheets of all station photos have been made for inclusion in the individual station files, and some, but not all, photo enlargements of selected photos of each cross section are processed.

Interpretive work, using some of the vigil network data, has been confined to analysis of bankfull discharge and rainfall-runoff relationships in an attempt to develop information on the homogenity (or lack thereof) for southeastern Montana streams. A final report on this phase of research is now ready for reproduction and drafting.

Perennial streams, particularly those that head in major mountain ranges in Wyoming and Montana, are consistent with predictable hydraulic geometry relationships. However, ephemeral streams in southeastern Montana do not bear the usual relationship between bankfull stage and recurrence interval. Instead of being characterized by a bankful flow event on the average of once every 1.5 years like the regional perennial streams, the local ephemeral streams achieve that discharge only once every 15 to 25 years or more. Additionally, the streams are highly irregular from site to site so that, for example, the ratio between the 25-year peak discharge and the 1.5-year peak discharge on streams of a fixed drainage size varies by a factor of two orders of magnitude between sites separated by but tens of miles.

Since it was found that it would not be possible to use simple channel geometry to predict the flow characteristics of ungaged sites, and since short periods of record (less than 20 years) at gaged sites would not produce reliable flow values, an attempt was made to develop other regional characteristics that would permit flow systhesis for any chosen site in the region. This work has compared precipitation intensity, drainage shape, and watershed aspect with flow variables and channel geometry. Using all available data, maps of the middle Yellowstone drainages that predict hydrologic homogenity and subdivide the region into three areas of varying homogenity have been developed.

The principal analytical finding of this research has been to demonstrate clearly that variability of hydrologic and hydrographic variables in the region is so high that conventional data synthesis and record extension are not valid. This is extremely significant, for example, in design and validity of interpretation of records taken from new short-period gaging stations established by various state and federal agencies. Standard U.S. Geological Survey synthesis will be of dubious value for periods of record that would normally be considered adequate elsewhere in the United States. These findings have been discussed with the Chief of the Water Resources Division of the USGS who has suggested that these findings parallel those of federal researchers in Nevada, but that there is no technical way around the problem at present.

ANTICIPATED ACTIVITIES NEXT QUARTER

During the first 2 months of the second quarter of 1976, the Vigil Network data files will be completed and in the hands of sponsoring organizations. Reproduction of photos and final drafting of regional and site maps will be completed. Work will continue through the summer on interpretation of the existing channel geometry and flow data. Specifically, analyses of long-term periodicity in precipitation and runoff data will be prepared to further test the hypothesis that the last 30 years (the entire period of record) were atypical.

Drafting of the plates in the hydrologic homogenity report will be completed and made available to organizations sponsoring the Vigil Network data collection. Flow and precipitation data will be extended through synthesis from tree-ring and other indirect paleoclimatic indicators of flood and precipitation activity.

CHANNEL PROCESSES AND DYNAMICS

INTRODUCTION

In evaluating channel processes and dynamics, several interrelated parameters must be considered. Among the most important of these variables are: streamflow regime, sediment and sediment transport properties, cross-sectional channel characteristics, and longitudinal channel characteristics. Presumably a change in any one of these parameters would have an effect on the others. In this study changes in flow rate due to development in the basin are to be hypothesized and the impact of these changes are to be assessed on the other variables mentioned above.

The physical environment of the river provides habitat for both terrestrial and aquatic organisms including vegetation, furbearing mammals, migratory birds, raptors, fish, and aquatic insects. Changes in the flow regime of the river will, in turn, change this physical environment and directly affect those species inhabiting the river. The magnitude and direction of the change in that physical environment are the subjects of investigation in this task.

Since the physical river environment has not yet been successfully modeled either physically or mathematically, a study such as this must interrelate what

quantitative devices exist to explain river mechanics with a large amount of qualitative observations and studies which have documented river processes and changes. Analytical and mathematical procedures have been developed for describing the present channel cross-sectional form and for establishing the sediment transport capability of a river. These are being applied to the system. River form and its changes are still the subject of much research and can be described only based on past river response, where documented, and on those physical principles known to govern the system.

This task has, to this point, been divided into three different subject areas. These are:

1. Channel geometry
2. Sediment transport sampling and prediction
3. Channel form and processes

The progress, conclusions to date, and proposed future work for each of these areas are discussed below.

CHANNEL GEOMETRY

Leopold and Maddock (1953) presented a method for quantitatively describing the cross-section geometry and hydraulic characteristics of river systems which has been successfully applied and expanded upon by others (Stall and Fok 1968, Stall and Yang 1970, Emmett 1972, Emmett 1975) and which will be used in this analysis. The premise of the procedure is that certain physical channel characteristics, e.g. top width (W), average depth (D), and average velocity (V) are related to discharge (Q) by the empirical relations:

$$W = aQ^b \qquad (1)$$

$$D = cQ^f \qquad (2)$$

$$V = kQ^m \qquad (3)$$

where a, b, c, f, k, and m are statistically determined constants. Combining equations (1) and (2) provides a relationship between cross-sectional area (A) and discharge:

$$A = (a+c)\, Q^{b+f} \qquad (4)$$

Each of these equations produces a straight line when plotted on log-log paper. The validity of any relationship presented using this format is easily tested by applying the relationship

$$W\, D\, V = Q \qquad (5)$$

Substituting equations (1), (2), and (3) into (5) gives

$$a\, c\, k = 1.0 \qquad (6)$$

$$b+f+m = 1.0 \qquad (7)$$

which are necessary for the validity of the physical system.

Equations (1), (2), and (3), called hydraulic geometry by Leopold and Maddock (1953), can be applied either at a station, that is, at a particular point along a stream, or in the downstream direction. Downstream hydraulic geometry is accomplished by applying the relationships at several points along a stream system for a constant frequency of discharge. For example, at several points where streamflow data are available in a watershed, W, D, and V are plotted against that Q which is equalled or exceeded 10% of the time at each point. In order to establish the downstream hydraulic geometry, then, points in the watershed where continuous streamflow data are collected are necessary.

Based on the approach described above, an analysis of hydraulic geometry in the middle and lower Yellowstone River Basin was undertaken. Since the only points in the basin where the necessary cross-sectional and flow data were available were the USGS and DNRC gaging stations, the analysis was based on these stations. Data provided by the USGS were taken from form 9-207, a tabulation of data collected during a discharge measurement. Similar data exist for DNRC stations.

At-a-station Hydraulic Geometry

At-a-station hydraulic geometry relationships were calculated by simple linear regression for all the stations shown in figure 22 and listed in table 64. A sample graph of the relationships for a single station is shown in figure 23. The b, f, and m exponents in equations (1), (2), and (3) represent the slope of the log-log plot and therefore show the rate of increase of W, D, and V, respectively, with Q. A flat curve shows a small rate of increase while a steep curve indicates a sharp increase. Even though the coefficients have little physical meaning, they are necessary to reconstruct the equations and, therefore, they are presented along with the exponents in table 65. As can be seen in table 65, there is considerable variation in the b, f, and m values.

Constant Frequency Hydraulic Geometry

An increase in streamflow in the downstream direction is assumed in most parts of the country; however, this is not always the case in Montana. In many situations, particularly for the more frequent flows in the major tributaries to the Yellowstone River, depletion for irrigation result in a stable or, at times, decreasing flow in the downstream direction. It is assumed, however, that the same processes work to form the channel whether the flow increases downstream or not. Therefore, an analysis of the hydraulic geometry based on a constant frequency of flow was performed for the stations with sufficiently long record for flood frequency analysis. The flow frequency used in this analysis was the 1.5-year flood which is claimed by some (Leopold et al. 1964, Emmett 1975) to be the frequency of the bankfull flow. This flow is considered to have channel-forming capacity. The constant frequency hydraulic geometry for the middle and lower Yellowstone Basin is shown in figures 24 and 25.

Dimensionless Hydraulic Geometry

An outgrowth of the constant frequency analysis is the dimensionless rating curve. These curves are given by the equations:

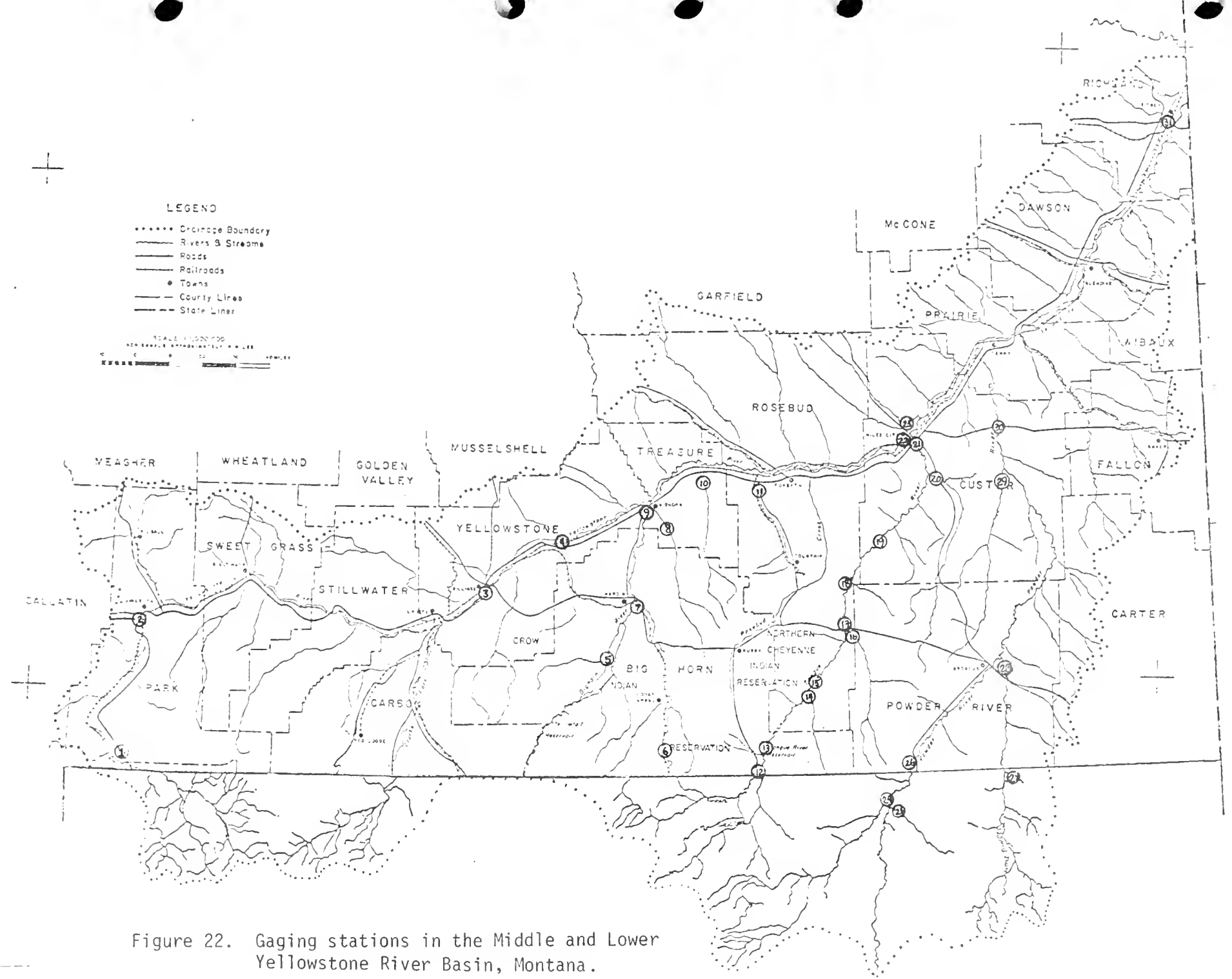


Figure 22. Gaging stations in the Middle and Lower Yellowstone River Basin, Montana.

TABLE 64. Gaging Stations in the Middle and Lower Yellowstone River Basins where Hydraulic Geometry was determined.

Figure 1 Number	Station Number	Station Name
1	06191500	Yellowstone River at Corwin Springs
2	06192500	Yellowstone River near Livingston
3	06214500	Yellowstone River at Billings
4	06217750	Fly Creek at Pompey's Pillar
5	06287000	Bighorn River near St. Xavier
6	06290500	Little Bighorn River below Pass Ck near Wyola
7	06294000	Little Bighorn River near Hardin
8	06294690	Tullock Creek near Bighorn
9	06294700	Bighorn River at Bighorn
10	06294940	Sarpy Creek near Hysham
11	06294995	Armells Creek near Forsyth
12	06306300	Tongue River at State line near Decker
13	06307500	Tongue River at Tongue River Dam
14	06307600	Hanging Woman Creek near Birney
15	42C020.00	Tongue River below Birney 1/
16	06307740	Otter Creek at Ashland
17	06307800	Tongue River near Ashland
18	06307830	Tongue River below Brandenburg Bridge near Ashland
19	42C070.00	Tongue River at SH Ranch 1/
20	06308400	Pumpkin Creek near Miles City
21	06308500	Tongue River at Miles City
22	06309000	Yellowstone River at Miles City
23	06309075	Sunday Creek near Miles City
24	06317000	Powder River at Arvada, Wyo.
25	06324000	Clear Creek at Arvada, Wyo.
26	06324500	Powder River at Moorhead
27	06324970	Little Powder River above Dry Creek near Weston, Wyo.
28	06325500	Little Powder River near Broadus
29	06326300	Mizpah Creek near Mizpah
30	06326500	Powder River near Locate
31	06329500	Yellowstone River near Sidney

1/ DNRC Stations

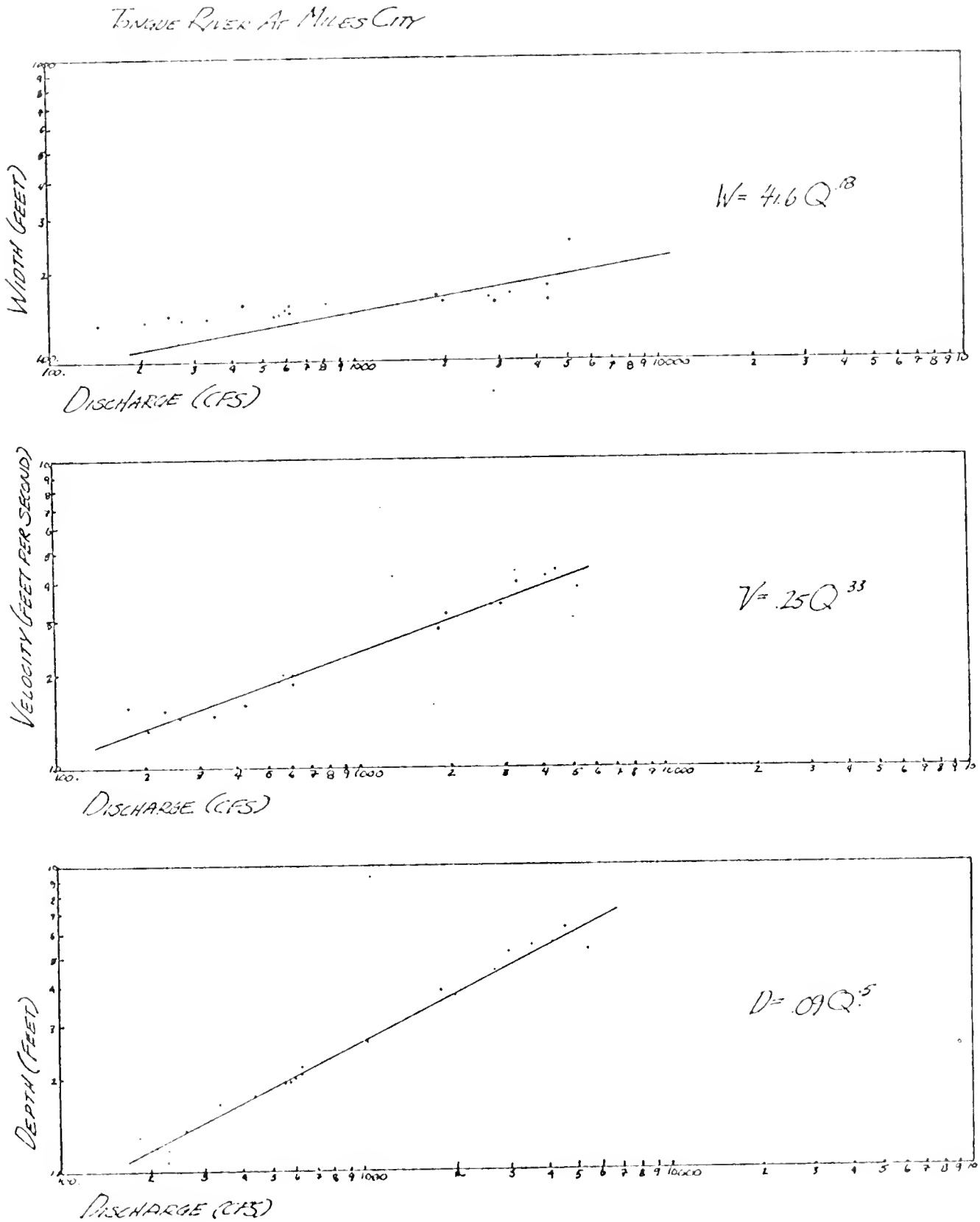


Figure 23. At-a-station hydraulic geometry for the Tongue River at Miles City.

TABLE 65. Coefficients and exponents for at-a-station hydraulic geometry, Middle and Lower Yellowstone River Basin.

Figure 1 Number	Station Number	$W=aQ^b$		$D=cQ^f$		$V=KQ^m$	
		a	b	c	f	k	m
1	06191500	100.4	.105	.23	.36	.043	.534
2	06192500	105.3	.12	.15	.39	.06	.5
3	06214500	161.4	.075	.97	.249	.007	.663
4	06217750	9.98	.18	.15	.6	.71	.19
5	06287000	43.95	.18	.75	.246	.03	.56
6	06290500	41.3	.72	.051	.609	.47	.32
7	06294000	21.3	.22	.179	.39	.562	.27
8	06294690	3.02	.53	.23	.37	.7	.08
9	06294700	133.01	.07	.503	.29	.032	.53
10	06294940	3.08	.32	.56	.28	.58	.38
11	06294995	5.7	.37	.25	.33	.71	.29
12	06306300	99.3	.04	.08	.49	.09	.48
13	06307500	37.3	.15	.16	.406	.15	.43
14	06307600	4.9	.36	.69	.19	.29	.44
15	42C020.00	61.9	.12	.03	.59	.49	.27
16	06307740	5.1	.32	.24	.46	.79	.21
17	06307800	100.4	.105	.23	.36	.04	.53
18	06307830	51.7	.12	.15	.43	.12	.44
19	42C070.00	139.8	.01	.06	.49	.102	.48
20	06308400	4.8	.49	.35	.25	.57	.25
21	06308500	41.6	.18	.08	.49	.25	.33
22	06309000	159.7	.13	.098	.43	.06	.43
23	06309075	7.06	.35	.19	.42	.76	.209
24	06317000	20.1	.25	.11	.45	.45	.29
25	06324000	37.98	.12	.283	.33	.087	.541
26	06324500	13.2	.39	.12	.38	.27	.34
27	06324970	9.7	.33	.16	.39	.63	.26
28	06325500	4.5	.44	.32	.33	.68	.22
29	06326300	18.8	.31	.11	.404	.31	.32
30	06326500	191.8	.12	.21	.39	.02	.49
31	06329500	4.3	.48	.26	.38	.93	.113

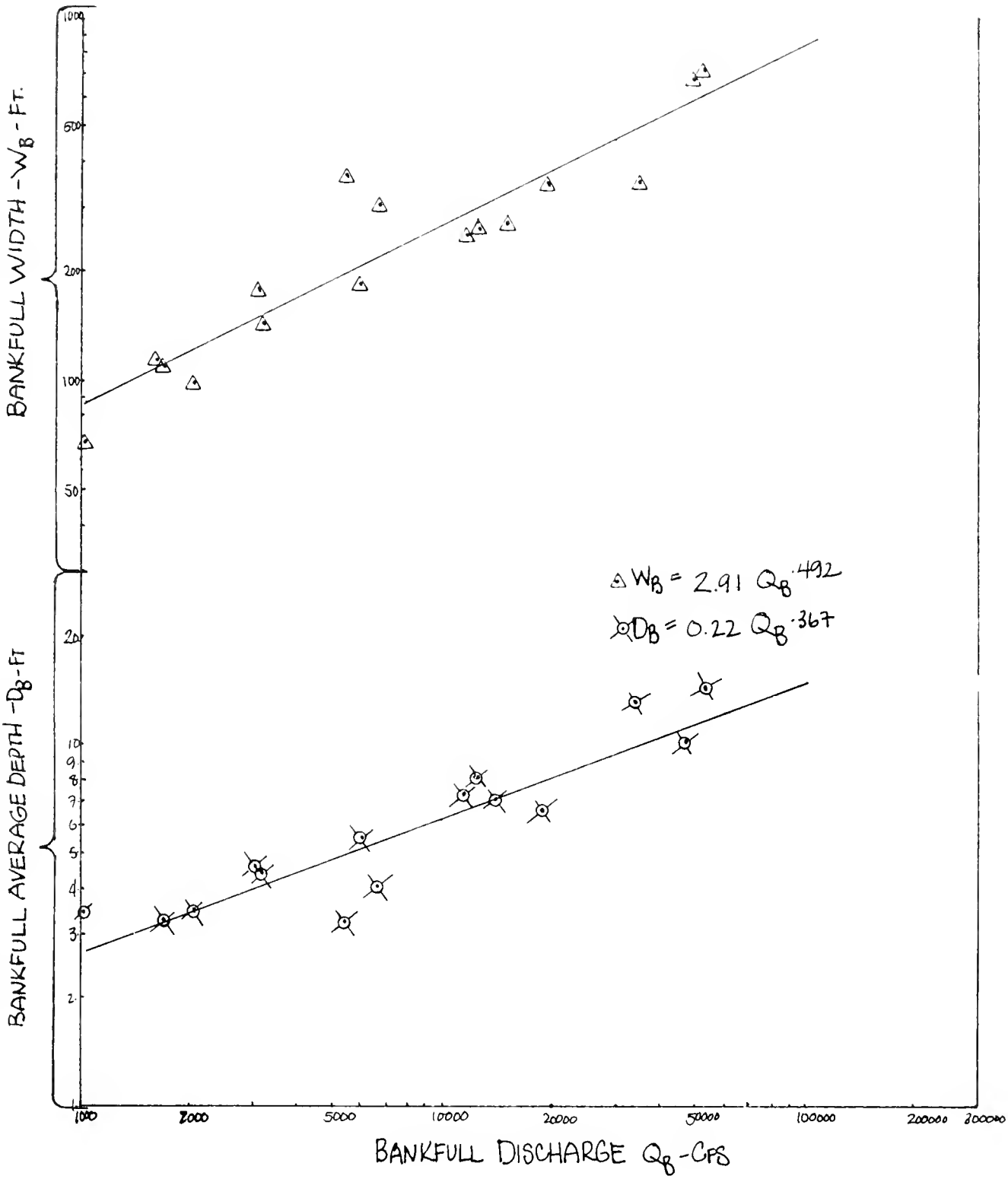


Figure 24. Lower Yellowstone River Basin constant frequency hydraulic geometry.

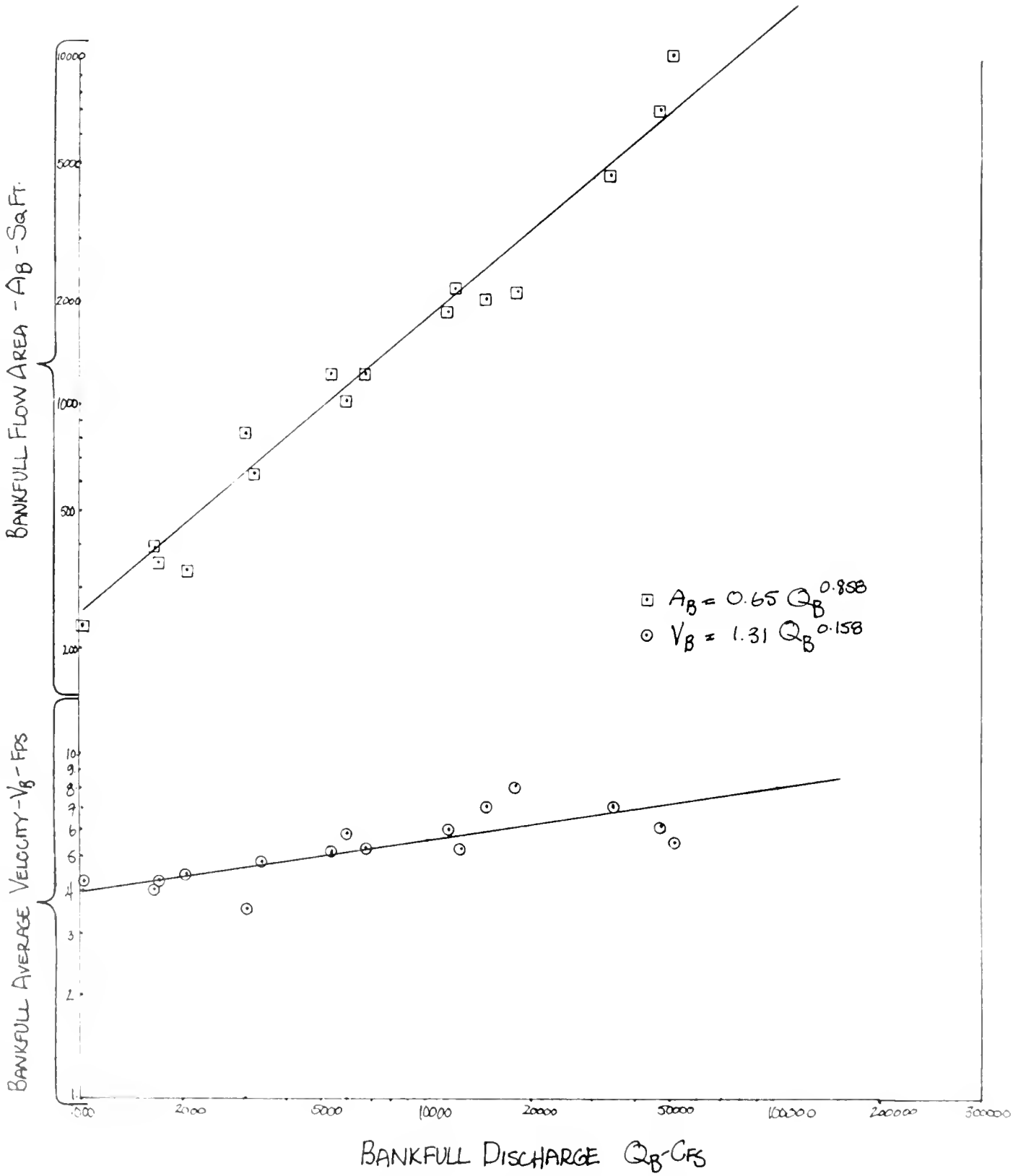


Figure 25. Lower Yellowstone River Basin constant frequency hydraulic geometry.

$$\frac{W}{W_B} = \left(\frac{Q}{Q_B}\right)^b \qquad (8)$$

$$\frac{D}{D_B} = \left(\frac{Q}{Q_B}\right)^f \qquad (9)$$

$$\frac{V}{V_B} = \left(\frac{Q}{Q_B}\right)^m \qquad (10)$$

$$\frac{A}{A_B} = \left(\frac{Q}{Q_B}\right)^{b+f} \qquad (11)$$

When flow durations and flood frequencies are attached to these curves, the result is useful in estimating channel characteristics or flow rates. Flow durations were provided by the USGS and flood frequencies were determined using USGS data and the procedures suggested by the Water Resources Council (1968). A skew of 0 was used as suggested by Beard (1962). The rating curves developed for the Yellowstone mainstem, the Bighorn River, the Tongue River, and the Powder River basins are presented in figures 26 through 29. The use of these rating curves should be confined to a particular stretch of channel similar to the ones used in development of the relations. Since USGS gaging station data were used this would imply a relatively straight stretch above a relatively stable flow control. Flow rates determined from these relations can be assumed constant through a reach of river, providing there is no significant inflow in the reach, and the usefulness can be expanded in this manner.

Historic Channel Changes

In order to evaluate changes in at-a-station and constant frequency hydraulic geometry, the data must be available over a considerable period of time. Therefore, only the stations that were included in the constant frequency analysis were also used here. To date, channel-geometry and flow-rate data have been gathered for the period of record at each station and stored in a computer file. A program has been developed for analyzing the data and analysis is currently underway. It is planned that this analysis will show the variation in the exponents of the hydraulic geometry equations and give an indication of channel response to past watershed development.

SEDIMENT TRANSPORT SAMPLING AND PREDICTION

Sediment transport is the process by which the river adjusts its cross-sectional and longitudinal characteristics and the composition of the bed to the flow regime and sediment load delivered to the channel. Many approaches have been presented to describe the mechanics of this process (Yang 1972). However, the basic processes, including the interrelationship of parameters such as flow regime, suspended load, bed load, bed material, and flow velocity, have not been adequately defined in one relationship which is universally applicable.

Yang and Stall (1974) have presented a method for computation of sediment transport through a concept called unit stream power, defined as the rate of energy expenditure per unit weight of water. The basic form of the equation is

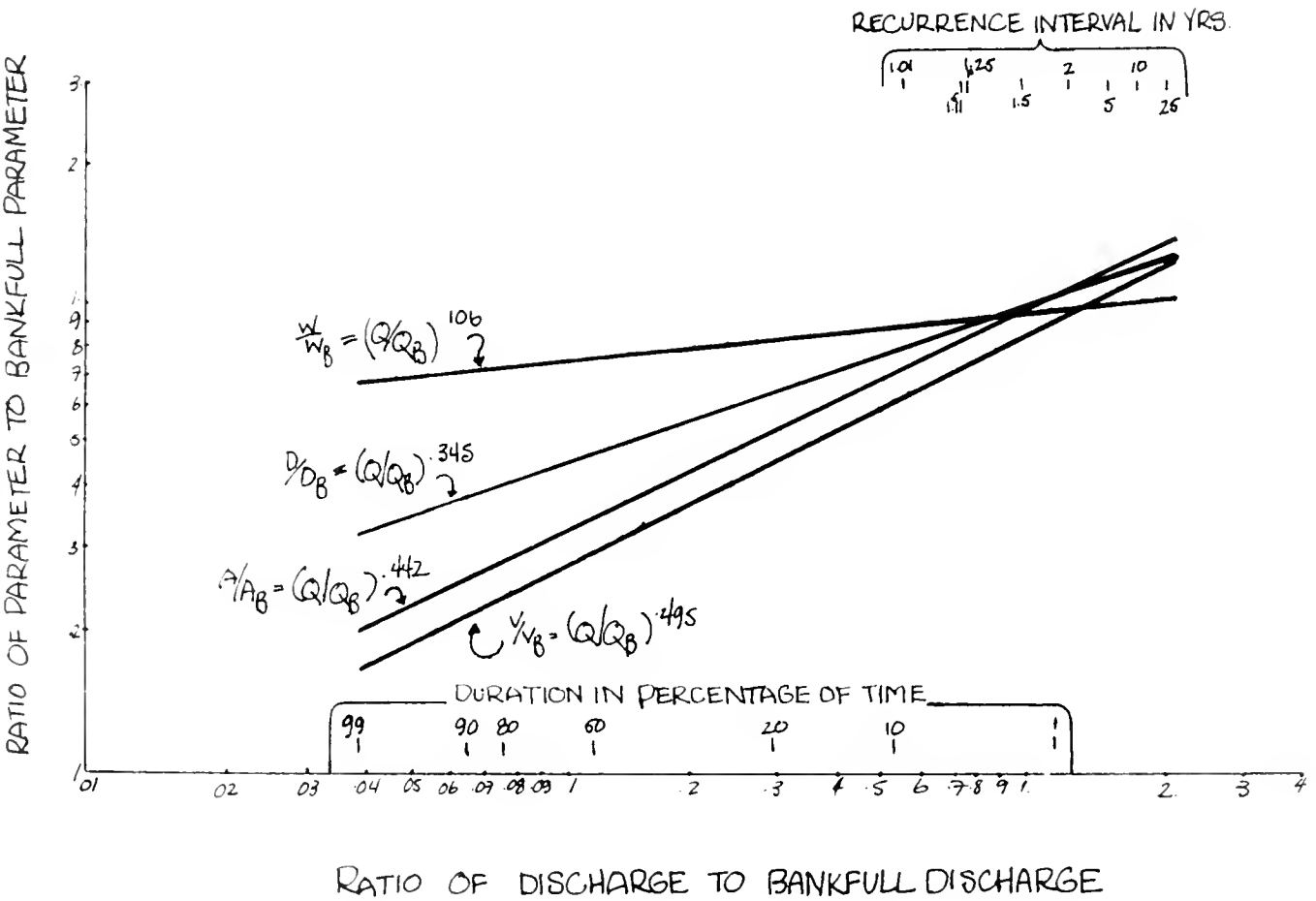


Figure 26. Dimensionless rating curve of the Yellowstone mainstem.

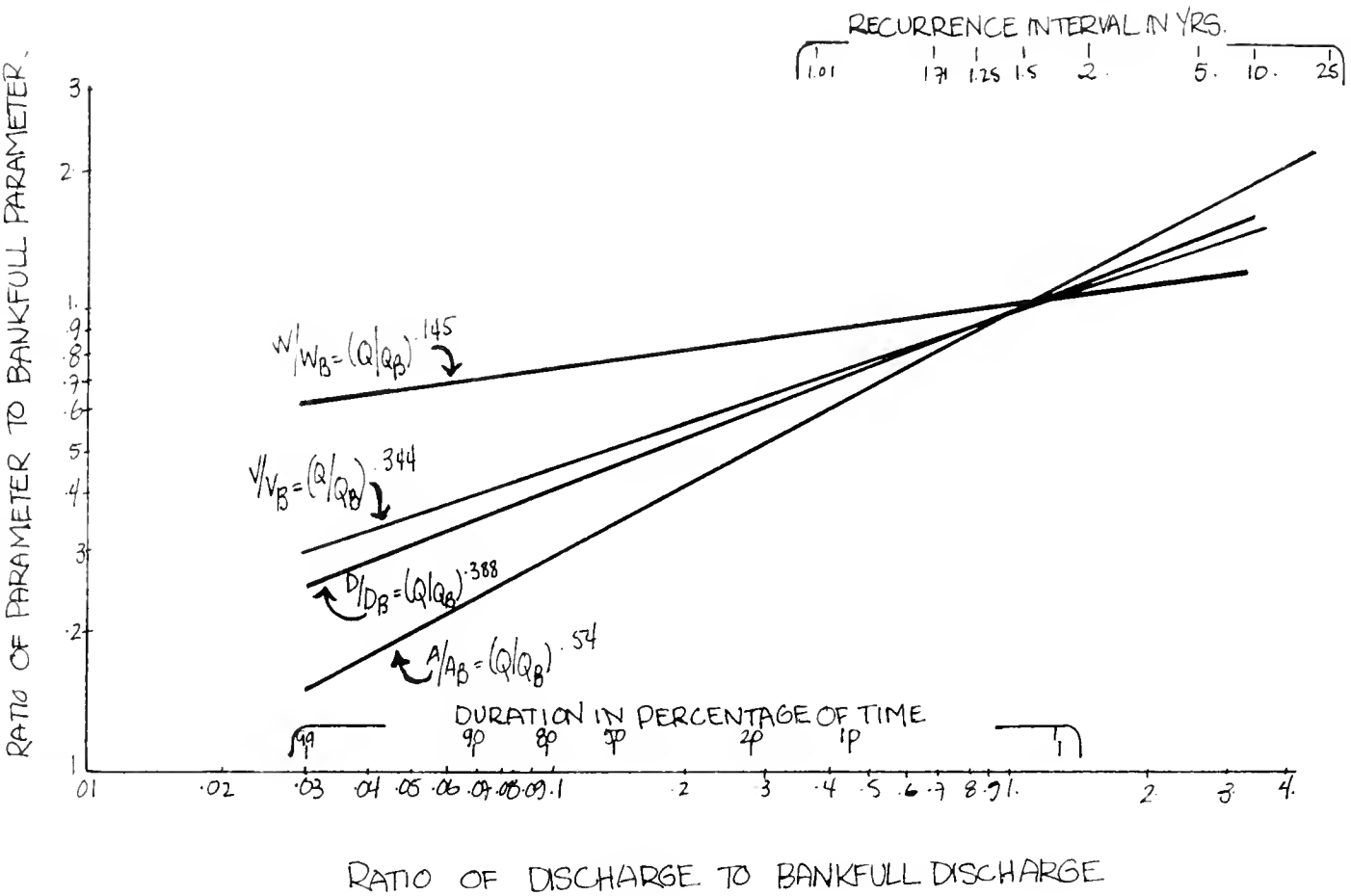


Figure 27. Dimensionless rating curve of the Bighorn River.

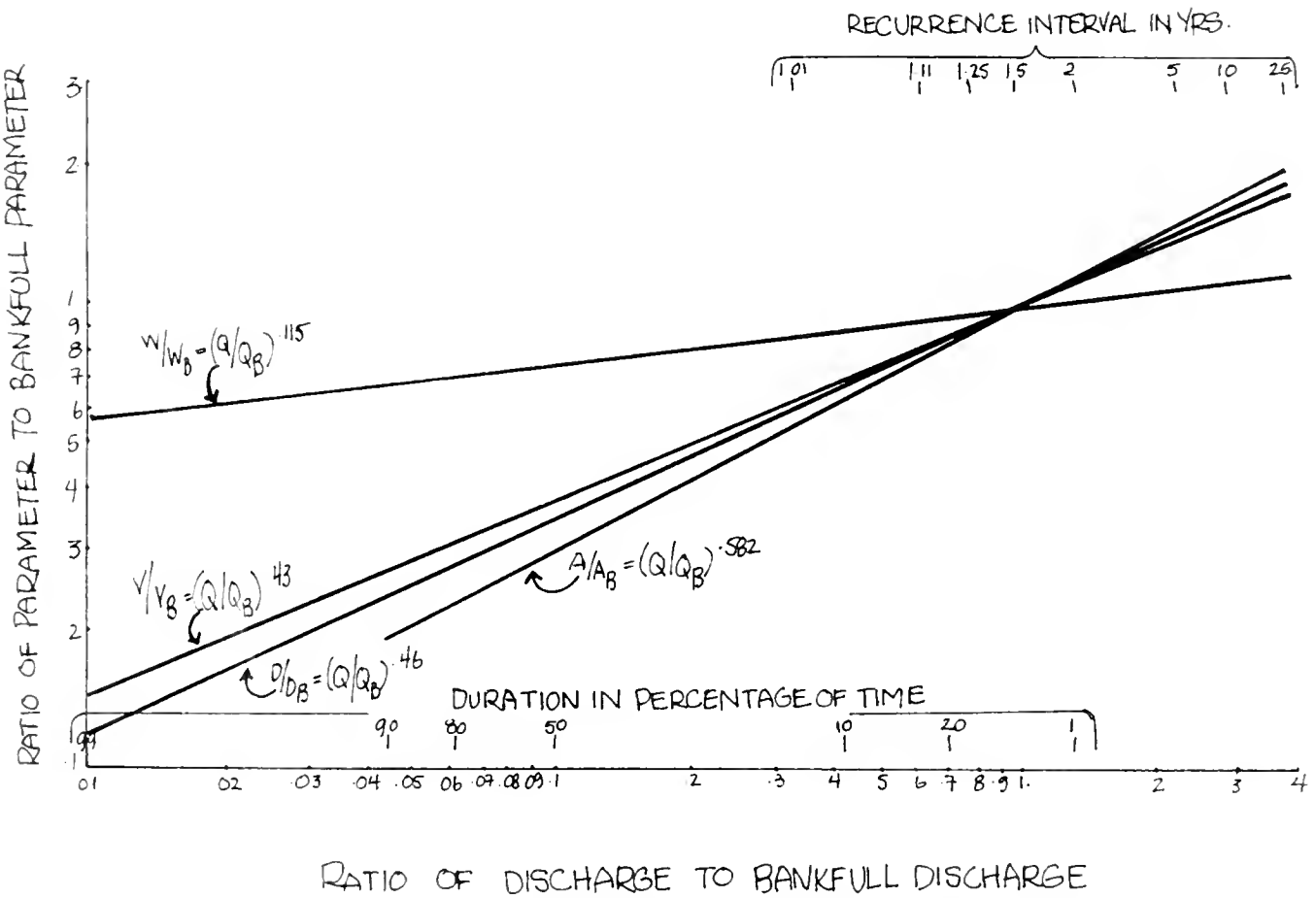


Figure 28. Dimensionless rating curve of the Tongue River.

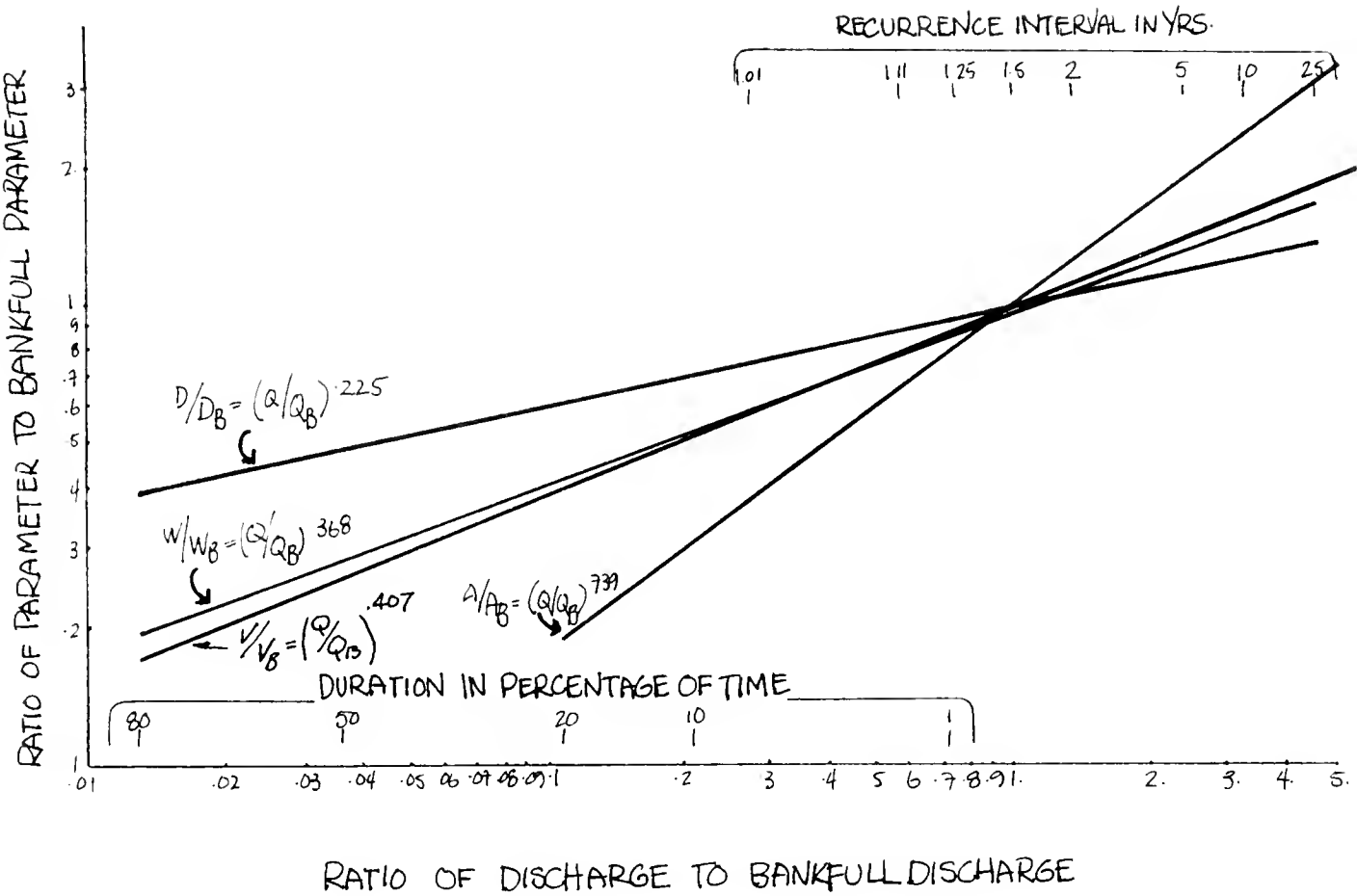


Figure 29. Dimensionless rating curve of the Powder River.

$$C_t = a(VS - V_{cr}S)^b \qquad (12)$$

where C_t is the total sediment concentration, V is the flow velocity, S is the friction slope, VS is the unit stream power, and $V_{cr}S$ is the critical unit stream power for sediment transport. The coefficient a and exponent b are statistically determined; Yang (1973) has shown that they are related to the particle size, particle fall velocity, viscosity, and shear velocity. This equation promises to be quite useful. Statistical coefficients have been developed based on river data collected at several sites. If data are collected so that the statistical coefficients can be verified or, if necessary, developed for the Yellowstone River, the results will be even more applicable.

In order to establish the applicability of the sediment transport equation as well as assemble some baseline data, a bedload sampling program has been designed for the spring of 1976 on the Yellowstone River. Data on suspended load are available at many points in the Yellowstone Basin. Data on bed load are nonexistent. And, since bed movement affects the aquatic and riparian terrestrial communities in terms of habitat alteration or maintenance, the relationship between flow rate, suspended sediment, and bed load will be established for a total prediction of impacts on these communities.

CHANNEL FORM AND PROCESSES

Although intimately related to channel geometry and sediment transport, channel form and processes are not, to date, as quantifiable. The longitudinal characteristics of a river, including slope and channel pattern, have been described and in some cases quantified (Yang 1971, Schumm 1963, Shulits 1941), but the universal applicability of such techniques has not been shown. For the purposes of this study, a qualitative investigation into the existing and past channel pattern and the channel processes at work appears to be as useful. Information from such an investigation will be directly related to habitat availability and changes in the basin.

Presently the river is being classified as to channel pattern after Kellerhals et al. (1975) using 1974 color aerial photography of the Yellowstone mainstem and the Bighorn River. In addition a report on the geomorphology of the mainstem is being prepared in an attempt to explain the channel form and processes at work. This will lead to at least a qualitative assessment of impacts on the river system.

ACTIVITIES PLANNED FOR NEXT QUARTER

During the coming quarter, a vigorous bed load sampling program will be undertaken at several stations along the Yellowstone mainstem and major tributaries. In conjunction with this, data on suspended sediment and corresponding flow rates will be collected from the USGS for several stations in the basin. Finally, an investigation into the channel processes and form in the study area will be conducted through field work and aerial photo analysis.

This task is approximately 65% complete.

TASK 9. WATER MODEL CALIBRATION AND RIVER BASIN SIMULATIONS . The Grantee shall calibrate the mathematical Montana water planning model to selected field impacts. The Grantee shall then conduct a series of computer runs to simulate the impacts of various degrees and configurations of water use.

STATE WATER PLANNING MODEL

ACTIVITIES DURING THE QUARTER

Calibration

At the time of the last quarterly report, subbasins 42KJ (mid-Yellowstone) and 43Q (Yellowstone at Billings) needed recalibration because of the necessary inclusion of Pryor (43E) and Rosebud (42A) creeks. These two subbasins have now been recalibrated, completing calibration of all subbasins of the Yellowstone River.

Simulation

Simulation runs were made on the following subbasins:

42B&C (Tongue River)

42K&J (Powder River)

43P&O (Bighorn)

42KJ&A (Mid-Yellowstone)

42L&M (Lower Yellowstone)

For the Tongue River subbasin, the following five simulations were run:

(a) High Scenario

(b) Intermediate Scenario (constant flow for fish and game)

(c) Intermediate Scenario (flow for fish and game having the same distribution as calculated by the NGPRP (1974)).

(d) Low Scenario

(e) Fish and Game Scenario

For the Powder River Basin, only the high scenario was run to find out

the potential yield of the subbasin with Moorhead Reservoir (active storage of 275,000 ac. ft.).

For the Bighorn (43P&O) and Mid-Yellowstone (43KJ&A) subbasins, it was not necessary to simulate the flows with the state water planning model because the demand was small compared to the streamflows. Flows were calculated by subtracting demand from historical flows.

For the lower Yellowstone subbasin (42L&M) the high scenario was simulated. The intermediate and low scenarios will be run during the next quarter.

The simulation runs on the Tongue River subbasin demonstrate that the State Water Planning Model can be adapted to simulate a wide range of operational policies.

Simulation results for 1960-1962, the dryest period simulated, for the Tongue low scenario are shown in figure 30. All other scenarios in the Tongue dewatered the river at least part of the time if not most of it. Information such as shown on figure 30 has been generated for all months for all years of record for all simulations which have been run to date. Results presented here are intended to demonstrate the kind of information being obtained and are not intended to show a complete picture or point out a special problem.

Plotting

The simulation results will be graphically displayed by plotting monthly values for the 30-year period simulated and 50% and 90% probability instream monthly flows based on the period of record utilized. Figure 31 plots these values for the Tongue River at its mouth; figure 32 plots them for the low scenario on the Tongue River.

In addition, plots are available showing reservoir storage, regulated flows, historic flows, and demands by month for the 30 years of each simulation.

ACTIVITY NEXT QUARTER

The scenarios will be revised to reflect results from Task 4 (agriculture). The revised subbasin scenarios will be simulated.

HYD2

ACTIVITIES THIS QUARTER

The HYD2 model is being used in addition to the State Water Planning Model for comparison purposes. This model, developed by the Bureau of Reclamation, provides for the accounting of available water in a basin by operating reservoirs to satisfy specified project requirements and any instream flow and water right requirements. If a water right or instream flow is specified downstream from a reservoir, no historic inflow is stored until these requirements are satisfied; then all inflow above the requirement is stored or passed through for project use.

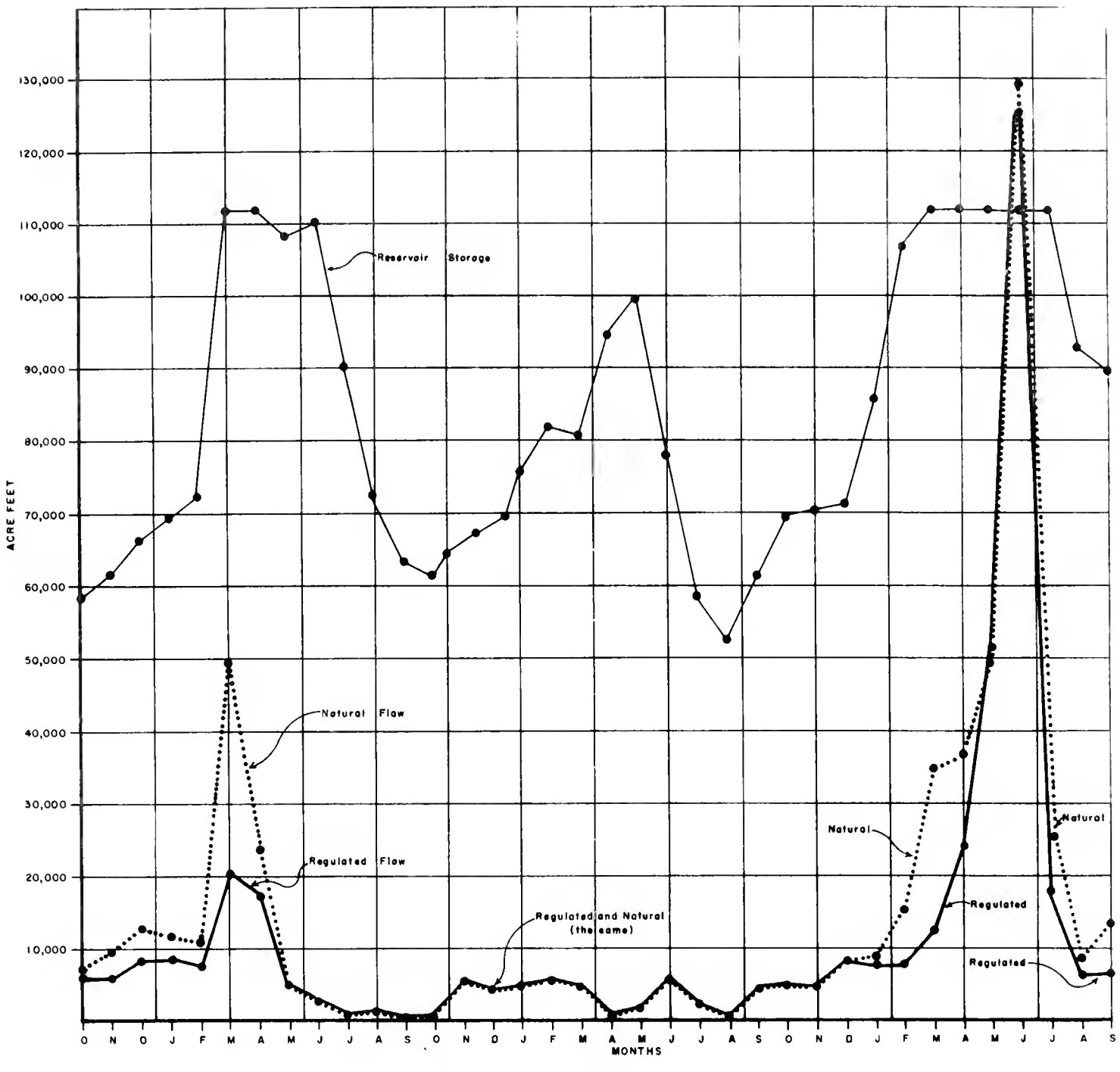


Figure 30. Tongue low scenario showing natural or historic flows and regulated flows and storage for 1960-1962.

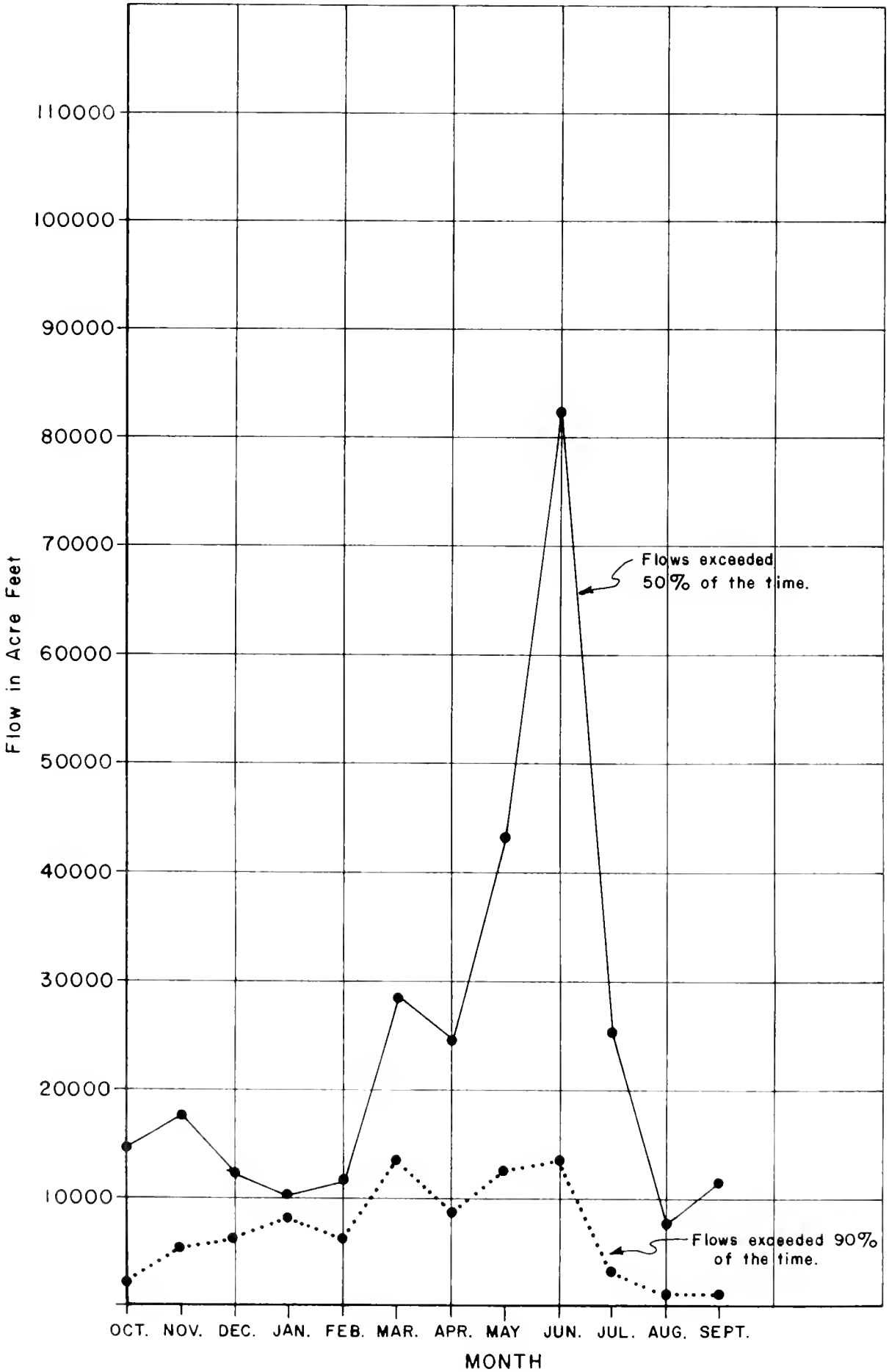


Figure 31. Tongue River Basin, natural flows at mouth.

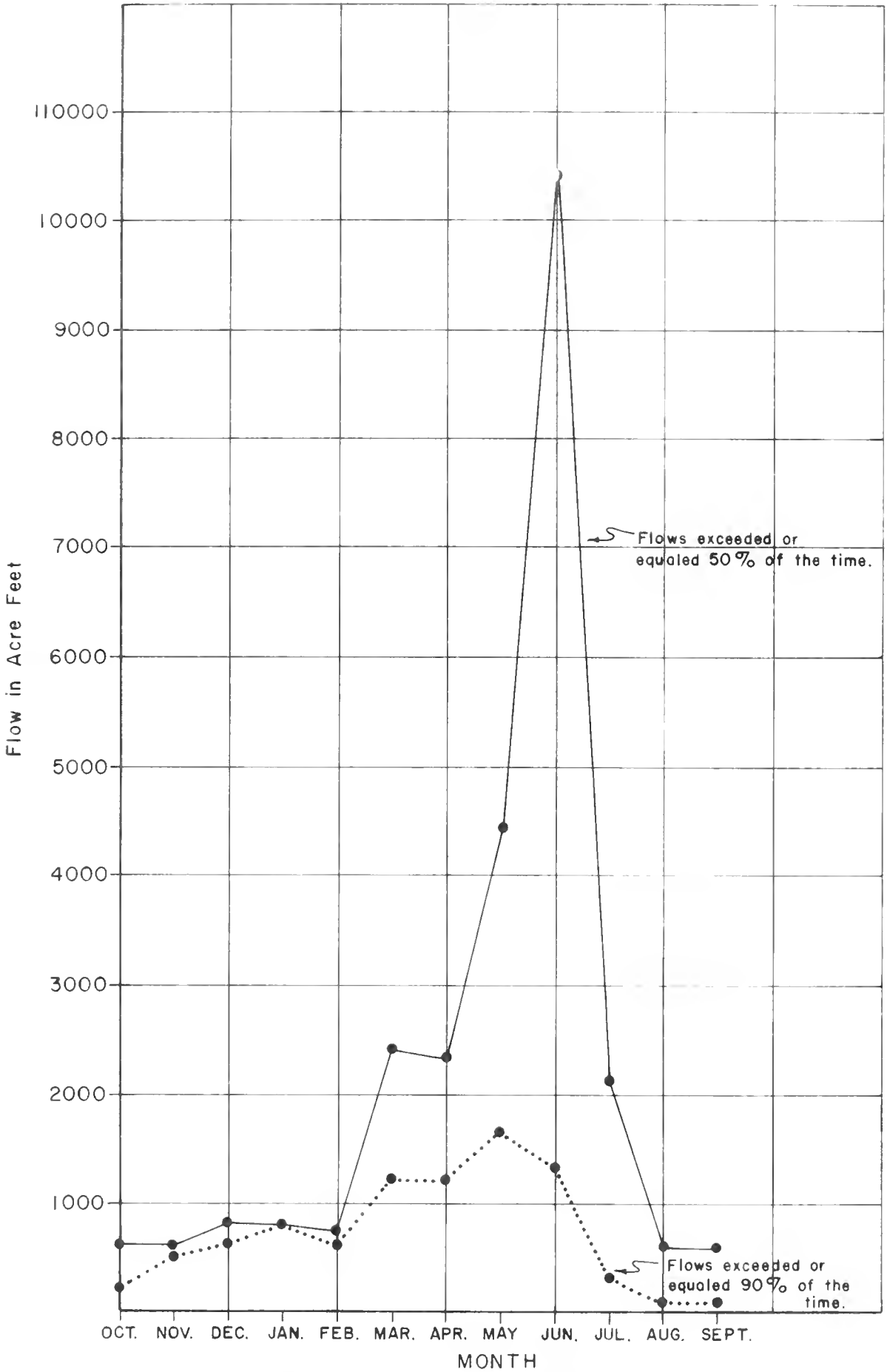


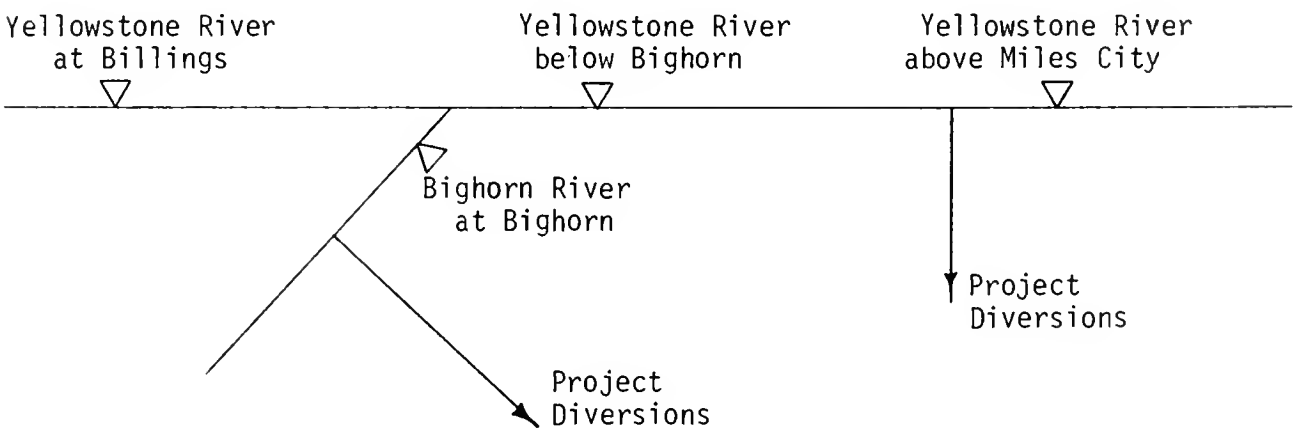
Figure 32. Tongue River Basin, regulated instream flows at mouth for low scenario.

The data required by the model are monthly values of runoff for each point where analysis is desired. The data used in this study were provided by the Bureau of Reclamation and are adjusted to reflect the level of development that existed in 1970 throughout the period of record. It was assumed that no major development resulting in any appreciable depletion was undertaken between 1970 and 1973 so that the period of analysis from 1944 to 1973 could be used, adding the 1971-1973 streamflow data in order to be consistent with the State Water Planning Model.

The development scenarios and Wyoming depletions used in the HYD2 study were the same as those used by the State Water Planning Model. Any differences in results reflect the inherent differences in model composition and input data.

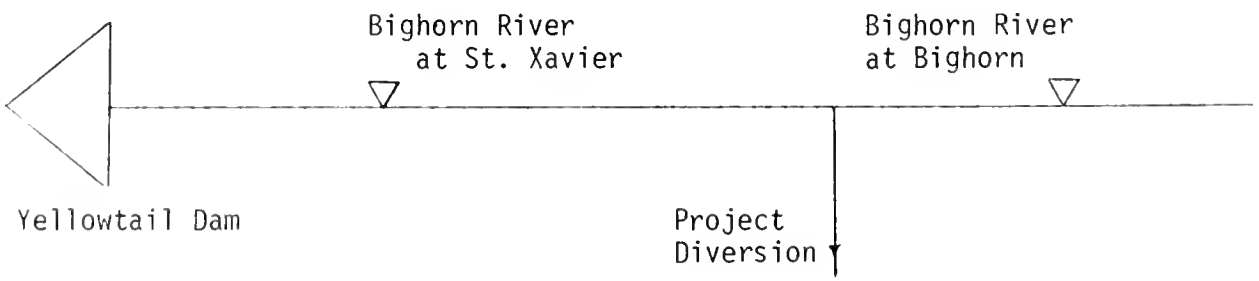
Mid-Yellowstone River Simulation

This simulation projects ample water for all levels of development with no change in the operation of Yellowtail Dam. The basin configuration is shown below.



Bighorn River Simulation

The Bighorn River Basin also seems to have ample water for the three hypothetical levels of development. The operation of Yellowtail Dam was reflected in adjustment of the runoff data at the St. Xavier station for the period of record. The basin configuration is shown below.



Tongue River Simulation

Four simulations were performed for the Tongue River subbasin. These were:

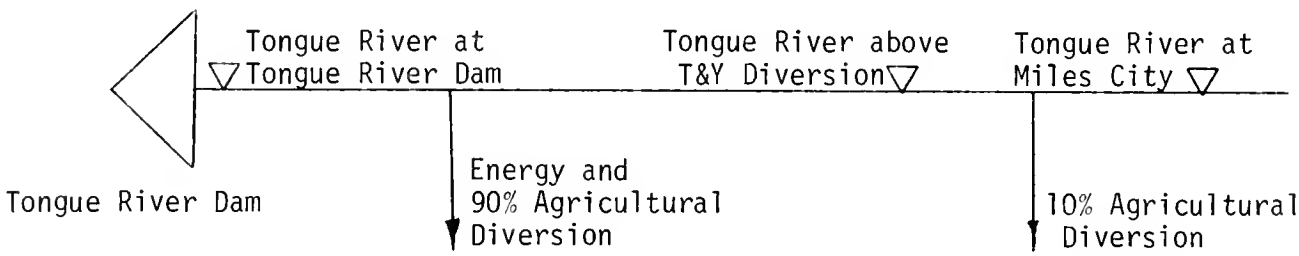
1. Low scenario with an additional 50,000 acre-feet (af) of storage at the present dam site and NGPRP (1974) instream flows.

2. Intermediate scenario with the New Tongue Reservoir (316,000 af) and a percentage of the NGPRP (1974) instream flows (maintaining the distribution) and a minimum reservoir storage of 50,000 af.

3. Intermediate scenario with the New Tongue Reservoir and a constant instream flow with a minimum reservoir storage of 50,000 af.

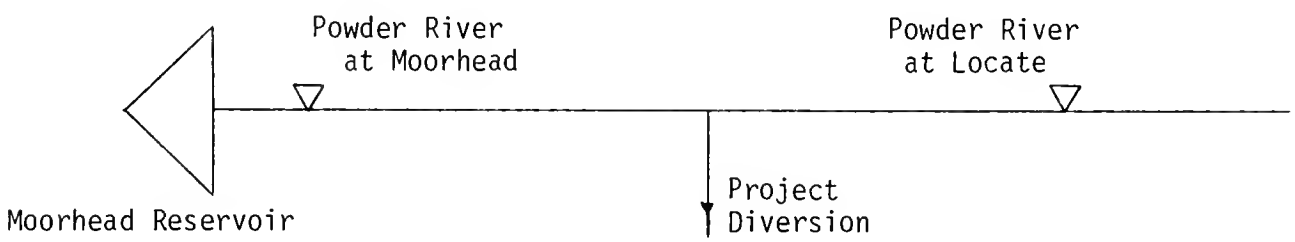
4. High scenario with no instream flow and no on-site storage.

Allowing no project shortages in the first simulation, all instream flows were met when historic flow was sufficient. The minimum reservoir storage reached was approximately 40,000 af. Satisfying the specified project requirements for the two intermediate simulations, either 60% of the NGPRP instream flow distribution or a constant flow of 160 cfs (9,600 af per month) can be attained. For the high scenario, shortages occur in 1961 and 1962; the reservoir is completely depleted in those years. The basin configuration for these simulations is shown below.



Powder River Simulation

In the high scenario it was not possible to completely meet any of the proposed water requirements in this subbasin without shortages, even with Moorhead Reservoir. If all the energy demand is met for the intermediate scenario, 100,000 afy is available for agricultural development. The basin configuration used in these scenarios is shown below.



Lower Yellowstone Simulation

Two simulations were performed for the Lower Yellowstone (42L&M) subbasin in order to reflect the total effects of development on the streamflow at Sidney:

1. The intermediate scenario for the entire basin above Sidney and an additional 84,000 afy of irrigation development in the lower Yellowstone above Sidney.

2. The high scenario for the entire basin above Sidney and an additional 231,000 afy of irrigation development in the Lower Yellowstone.

The flow at Sidney was appreciably depleted only in 1960 and 1961. In 1960 a minimum flow of 95,000 af in the month of August resulted, and in 1961 a minimum of 3,500 af was experienced in August. All other monthly flows were above 100,000 af at all times for all cases.

Task 9 is about 75% completed.

TASK 10. COMMENCEMENT OF FINAL IMPACT EVALUATION OF WATER WITHDRAWALS AND WATER DEVELOPMENT ON THE MIDDLE AND LOWER PORTIONS OF THE YELLOWSTONE RIVER DRAINAGE, MONTANA. The Grantee shall commence an analysis in three stages:

A) Determine the mixes of coal-based water consumption to be evaluated in future years.

B) Project the demands that other water users will impose in future years.

C) Analyze the field impacts of the foregoing competing demands.

Phase (A) of this Task has been discussed under Task 5; phase (B) is included in Tasks 4 and 5; phase (C) is an integral part of Tasks 1-9.

TASK 11. COMMENCEMENT OF ECONOMIC EVALUATION OF WATER WITHDRAWALS AND WATER DEVELOPMENT ON THE MIDDLE AND LOWER PORTIONS OF THE YELLOWSTONE RIVER DRAINAGE, MONTANA. The grantee shall commence an economic evaluation of the impacts and assessments set forth in the foregoing tasks. The Grantee shall provide such coordination of the foregoing tasks as is necessary to make this economic evaluation.

INTRODUCTION

The economic analysis of preliminary impacts of water development on the Yellowstone River may be summarized as follows: there will be some absolute dollar loss incurred by some segments of society from the allocation of Yellowstone River water in some of the ways investigated. However, it is not possible to estimate net gains or losses or determine who incurs them until the levels of impact of each function are quantified for each scenario.

At the present time, only the dollar value of water in each marketable use (see below) can be reported. Evaluating the impacts in terms of dollars awaits quantification of those impacts.

PRELIMINARY ECONOMIC IMPACT OF FLOW REDUCTIONS

IMPACT ON RECREATION

In the case of recreation (which for the purposes of the economic analysis includes Tasks 1, 2, and 3), the high scenario is estimated to result in some decrease in the opportunity to recreate, partially because of an expected decrease in the desirability of boating and floating. For the intermediate scenarios, boating access and conditions would improve, partially accounting for an increase in the opportunity to recreate in the river sections analyzed.

It has not been possible to assess the amount of decrease in one scenario or increase in the other. For example, determining that each high-quality recreation day is worth $9.00 (Young and Gray 1972) is of limited utility in weighing tradeoffs among uses unless the magnitude of the loss or gain can be quantified.

It is an assumption of the study that water-based recreation contributes to the well-being of society. The value of that contribution is not degraded if substitutes are available for any opportunities destroyed. Four possible substitute or additional sites are being studied as a part of Task 7.

The importance of fishing success to recreation enjoyment has not been quantified (Erickson 1976). So, even if the decreases in fish habitat could be related to fish populations for different scenarios, decreases are not now

adequate information for quantification of benefits and costs. It is hoped that the second full field season will make that quantification possible and allow recreation evaluation to proceed quantitatively.

Severe impacts on furbearing mammal habitat have been predicted for the intermediate and high scenarios, but the population of animals, within limits, apparently has little effect on trapping activity (Martin 1976). Pelt prices apparently have a similarly small effect. The magnitude of any decrease in the level of trapping income, therefore, is not possible to predict at this time.

IMPACT ON AGRICULTURE

For irrigation, the value of water to the farmer is no more than his capacity to repay the costs of the irrigation system and its operation, or $15.50-$101.50/acre-foot, depending on the crops grown (See Task 4 of this report). To society, the value of the water in that use is equal to the value of the food produced over what would be produced under dryland conditions, if it could not be produced in another way or in another place. The value of the water to produce the food is also a function of what values must be foregone in other uses. It may be higher or lower than the repayment capacity of the farm.

Water quality for irrigation was predicted to be a possible problem 10 percent of the time for the high scenario in the Bighorn River (Thomas 1976). The agricultural value lost by upstream dewatering and consequent increased TDS concentration equals the willingness-to-pay of those downstream irrigators who lost the option of irrigating with adequate-quality water.

IMPACT ON INDUSTRY

The value to industry of water in energy uses has been variously estimated at $100-$200/af for thermal electric plant cooling (Stroup and Townsend 1974) and $308.45/acre-foot for gasification (North Dakota State Water Commission 1975). This latter figure is probably low, as it assumes a lower-than-currently-accepted price for the synthetic gas produced (Stroup and Thurman 1976). The North Dakota State Water Commission also estimated the value of the water used in thermal electric generation at from $145.47-$308.97/af, depending on the size of the facility. These costs represent the contribution of water to the value added from production (analogous to repayment capacity in agriculture) of the energy product. The value to society of that water in an energy use may be higher if the energy is necessary and an alternative method of producing it is not available in the right place at the right time. It may be lower if opportunities to use the water in more valuable ways must be foregone in order to use it to produce energy.

IMPACT ON MUNICIPAL WATER SUPPLIES

The North Dakota State Water Commission (1975) used a water value of 83¢/1000 gallons ($270.50/af) to represent development and treatment costs of saline ground-water purification as a substitute for good surface water--a value

consistent with that experienced in several western North Dakota communities with saline water sources. The difference between $270.50 and the cost of achieving present quality would have to be considered in calculating additional costs due to impacts assessed in this project.

ACTIVITIES PLANNED FOR NEXT QUARTER

Refinements in quantification of physical impact data will be evaluated as they become available. Verification of dollar values to use of physical data allow will continue.

To date, Task 11 is approximately 75% complete.

TASK 12. EVALUATION OF WATER MODEL. The Grantee shall provide an evaluation of the utility of the water modeling method used pursuant to this grant, with attention to its potential utility as a prototype in the Old West region of Montana, Wyoming, North Dakota, South Dakota, and Nebraska.

WATER MODEL EVALUATION

ACTIVITIES DURING THE QUARTER

No significant work has been done on this task.

ACTIVITIES NEXT QUARTER

During the next quarter criteria will be established for evaluation of water modeling methods. In addition to the State Water Planning Model and HYD2 which have been used, models developed for use in Texas will be evaluated and tested if resources allow. Other models, such as SSARR, will also be evaluated as much as possible.

FINANCIAL INFORMATION

Through March 31, 1976

	Quarter	Total
Salaries	26,606.52	137,166.96
Wages	1,417.20	6,926.41
Benefits	3,513.24	17,401.45
Total Personal Services	31,536.96	161,494.82
Contracted Services	67,672.78	163,208.99
Supplies & Materials	62.12	4,090.14
Communications	111.09	1,467.27
Travel	1,490.96	14,667.15
Rent	185.44	1,944.84
Repair & Maintenance	4.80	143.15
Other Expenses	20.00	1,241.72
Total Operating Expenses	69,547.19	186,763.26
TOTAL DIRECT EXPENSES	101,084.15	348,258.08
INDIRECT COSTS (5.77%)	5,832.56	20,094.50
TOTAL COSTS TO DATE	106,916.71	368,352.58
Funds on Hand March 31, 1976		25,613.42
Estimated Funds needed for quarter ending June 30, 1976		
Salaries, wages, & benefits		39,450.00
Contracted services		55,700.00
Supplies & materials		1,410.00
Communication & transportation		400.00
Travel		3,180.00
Administrative		5,900.00
Other		1,960.00
		108,000.00

DETAIL OF CONTRACT PAYMENTS

	Quarter	Total
DEPT. OF HEALTH:		
Personal Services	15,407.94	38,276.57
Contract Services	13.27	13.27
Supplies & Materials	835.08	3,739.29
Communications	9.19	9.19
Travel	1,490.83	3,417.62
Other Expenses		14.40
Total	17,756.31	45,470.34
DEPT. OF FISH & GAME:		
Personal Services	34,022.00	71,348.59
Contracted Services	260.99	637.29
Supplies & Materials	1,882.04	4,596.97
Communications	518.10	849.51
Travel	9,868.98	17,313.32
Aircraft Rental	2,486.80	7,678.20
Utilities	4.80	9.60
Repairs & Maintenance	430.86	1,336.80
Other Expenses	29.73	31.33
Total	49,504.30	103,801.61
UNIVERSITY OF MONTANA:		
Personal Services		2,905.60
Supplies & Materials		174.53
Travel		185.65
Other Expenses		5.60
Total	-0-	3,271.38
SATISH NAYAK, Computer Systems Analyst		4,215.60

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